TETLIN NWR / SCOTTIE CREEK
EARTH COVER CLASSIFICATION

USER'S GUIDE

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Many thanks are extended to the folks at Tetlin National Wildlife Refuge who participated in the collection of field data and those who assisted with the field logistics and data entry. Gail Harper-Collins (USFWS) was instrumental in the planning process of this project, coordinated the field logistics, and served as the vegetation caller during the field sessions. Ruth Spell (DU, Inc.) served as the navigator for field data collection and performed the image processing. Simon Wigren and Drew Grimes served as base managers and entered the field data on a daily basis. Quicksilver Air, Inc. provided helicopter support, and pilots Rick Swisher and Mike Terwilliger flew the helicopters in a manner that allowed for safe and efficient field data collection. Amy Leach (DUC) was instrumental in the planning process for the Scottie Creek portion of the project. Dan Fehringer (DU, Inc.) and Al Richard (DUC) provided management support.

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Abstract

In 2005, the U.S. Fish and Wildlife Service and Ducks Unlimited, Inc. began a mapping effort to produce earth cover data for three National Wildlife Refuges (NWRs) in the state of Alaska: Tetlin NWR, Alaska Peninsula/Becharof NWRs, and Yukon Delta NWR. At the same time, as part of Ducks Unlimited Canada's Western Boreal Forest Program, earth cover mapping of the Scottie Creek drainage in Yukon Territory was being planned. These efforts were combined, and the Tetlin NWR and Scottie Creek Earth Cover Mapping project was undertaken as a cross-border mapping project to produce a seamless dataset for both of these programs. In addition to the Alaska Region of the U.S. Fish and Wildlife Service, funding partners included Ducks Unlimited, Inc.; Yukon Territorial Government, Department of Environment; The Pew Charitable Trusts; the Canadian Boreal Initiative; and U.S. Fish and Wildlife Service, through the North American Wetlands Conservation Act.

The project involved the classification of nearly 2.2 million hectares (5.4 million acres) from one Landsat 5 Thematic Mapper (TM) satellite scene acquired during the summer of 1999. The classification scheme was based on Viereck et al. (1992) and has been applied successfully by Ducks Unlimited for earth cover mapping in boreal Alaska and Canada. Field data was collected via helicopter at 397 sites during the field session from June 19-29, 2005. Following the completion of fieldwork, the field sites were divided into training vs. accuracy assessment sites using a stratified random selection process. Approximately one third of the sites were set aside for later use in the accuracy assessment.

The imagery was segmented into image objects and classified with Definiens eCognition Professional 4 image analysis software using membership functions and supervised classification methods. Once the classification process was completed, accuracy assessment was performed. The overall accuracy of the earth cover classification map was 72%, and increased to 79% with application of fuzzy logic (+/- 5% variation in interpretation).

1.0 Introduction

In 2005, the U.S. Fish and Wildlife Service and Ducks Unlimited, Inc. (DU) began a mapping effort to produce earth cover data for three National Wildlife Refuges (NWRs) in the state of Alaska: Tetlin NWR, Alaska Peninsula/Becharof NWRs, and Yukon Delta NWR. At the same time, as part of Ducks Unlimited Canada's Western Boreal Forest Program, earth cover mapping of the Scottie Creek drainage in Yukon Territory was being planned. These efforts were combined, and the Tetlin NWR and Scottie Creek Earth Cover Mapping Project was undertaken as a cross-border mapping project to produce a seamless dataset for both of these programs.

Ducks Unlimited has been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. These mapping efforts have included cooperative efforts between DU and multiple federal, state, and private cooperators and have utilized a proven method of earth cover mapping that provides an inventory of Alaska's land base that can be used for regional management of land and wildlife.

In Canada, DU and Ducks Unlimited, Canada (DUC) have partnered with provincial, territorial, and national governments; First Nations; industry; and private organizations to map large portions of the western boreal forest. The western boreal forest ecosystem of Canada comprises over 3,000,000 km^2. It is a vast expanse of forest interspersed with lakes, rivers, bogs, fens, marshes and swamps that provide important habitat for waterfowl and a myriad of other wildlife. In recent years, this region has experienced an increase in resource extraction and development. The consequences of these activities on wetland systems remain largely unknown. These mapping efforts are providing baseline earth cover datasets that are utilized in conservation planning efforts and protected area strategies throughout the western boreal forest region.

DU's mapping protocols rely on helicopter-based fieldwork for efficient and accurate data gathering, and state-of-the-art image processing techniques to produce high quality earth cover datasets. Using a hierarchical classification scheme (derived from Vierick et al, 1992) that has been reviewed by multiple agencies and approved by the Alaska Geographic Data Committee, DU's past mapping efforts have produced the most extensive and consistent earth cover database available for Alaska. More than 65 million hectares (160.9 million acres) have been mapped throughout Alaska, accounting for more than 40% of the entire land base, 90% of Bureau of Land Management lands, and more than 25% of U.S. Fish and Wildlife Service lands. More than 50.9 million hectares (125.9 million acres) have been mapped in the western boreal forest of Canada. The hierarchical classification scheme and large extent of this dataset make it useful for both refuge-level and regional-scale analysis.

This report describes the Tetlin NWR and Scottie Creek Earth Cover Mapping Project. The project involved the classification of nearly 2.2 million hectares (5.4 million acres) of a Landsat 5 Thematic Mapper satellite image acquired during the summer of 1999. This earth cover map provides a dataset that resource managers can combine with information on wildlife species abundance, seasonal distributions, reproductive rates, movements, etc. in a

GIS to more accurately assess wildlife habitat status and trends. In addition earth cover data can provide better information for conservation planning and resource management, including the management of fire, recreation, subsistence, public access, and other human activities.

2.0 Project Objective

The objective of this project was to develop a baseline earth cover inventory from Landsat TM imagery for Tetlin NWR and surrounding areas, including the Scottie Creek area in Canada. This baseline inventory is comprised of a digital earth cover map of the project area and a comprehensive digital database of field data and photographs that can be easily integrated into a geographic information system (GIS). GIS provides the ability to spatially relate the earth cover data to wildlife, sociological, and other pertinent datasets, allowing researchers, biologists, and managers to identify crucial areas for wildlife, perform analysis of related habitats, plot movement patterns for large ungulates over the landscape, and generate risk assessments for proposed projects.

3.0 Partners

The Tetlin NWR / Scottie Creek Earth Cover Project was the result of a multi-agency and international cooperative effort. Primary funding was provided by the U.S. Fish and Wildlife Service, Alaska Region. Additional funding was provided by DU; DUC; Yukon Territorial Government, Department of Environment; U.S. Forest Service; The Pew Charitable Trusts; Canadian Boreal Initiative; and U.S. Fish and Wildlife Service, through the North American Wetlands Conservation Act.

4.0 Project Area

The Tetlin NWR / Scottie Creek project area encompasses 2,183,362 hectares (5,395,184 acres) in eastern Alaska and Canada's Yukon Territory (Figure 1). It is roughly centered on Tetlin NWR (greater than 376,350 hectares) and includes the northern portion of Wrangell-St. Elias National Park which abuts Tetlin NWR to the south. The Alaska Highway and the Tanana River run east-west through the center of the project area and the Taylor Highway cuts through the northern half of the project area. The Nabesna River and the Chisana River flow from the Alaska Range north into the Tanana River. The project area was extended southward into Wrangell-St Elias National Park to the edge of the satellite image. This same satellite image was being used by the Park Service for mapping the park. The mapping of these two adjacent areas by two different entities will provide a rare opportunity to compare the results from two mapping methods.

The project area encompasses portions of five ecoregions as defined by the Ecoregions of Alaska and Neighboring Territory (Nowacki, et al., 2002) (Figure 2). The northern half of the project area lies within the Yukon-Tanana Uplands ecoregion and is characterized primarily by low, rounded hills and mountains, but also includes some taller mountains with rugged peaks (Figure 3). The landscape is dominated by black spruce on north facing slopes and white spruce, birch, and aspen on the south-facing slopes. The valley bottoms are characterized by woodland black spruce, low shrubs, and tussock-forming sedges. Wildlife in this region includes caribou, moose, lynx, marten, and black and brown bears. (Nowacki, et al, 2002) Permafrost is discontinuous (Ferrians, 1998).

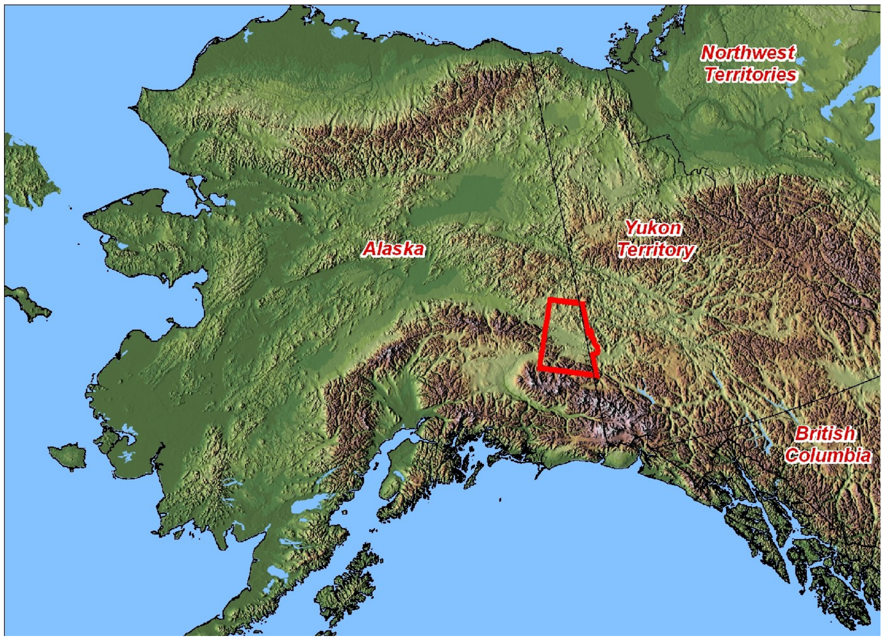


Figure 1. Tetlin NWR / Scottie Creek project location.

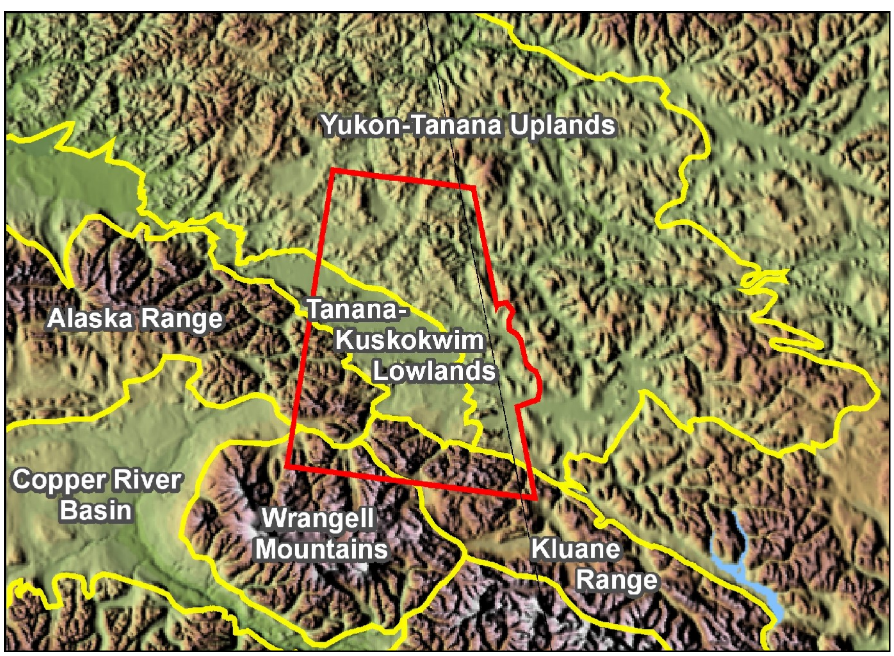


Figure 2. Ecoregions within the Tetlin NWR / Scottie Creek project area.

Figure 3. Low, rolling hills of the Yukon-Tanana Uplands ecoregion.

The central part of the project area, including most of Tetlin NWR, is within the Tanana-Kuskokwim Lowlands ecoregion. This region consists of a relatively flat alluvial plain that slopes gently down from the Alaska Range towards the Tanana River. Soils are poorly drained and the region has an abundance of wetlands, including thaw lakes and collapse-scar bogs and fens (Figure 4). The permafrost in this area consists of large areas of thick to thin permafrost with numerous isolated masses of permafrost in between these areas (Ferrians, 1998). The landscape is dominated by stunted black spruce in poorly drained areas, white spruce and balsam poplar along rivers, and spruce (both black and white), birch, and aspen on higher terrain. Tall shrub and low shrub willow communities are associated with riparian features. Low shrubs with tussock-forming sedges are common on permafrost flats. The numerous lakes and other wetlands of the lowlands provide important habitat for migrating and nesting waterbirds, including trumpeter swans. Large mammals found in the lowlands include moose, black bears, caribou, lynx, and numerous furbearers (Nowacki, et al., 2002).

The mountainous southern part of the project area lies within three ecoregions (Nowacki, et al., 2002): the Alaska Range, the Kluane Range, and the Wrangell Mountains ecoregions. Although of different geologic composition, these three ecoregions are characterized by similar land cover (Figure 5). Much of the higher elevations are barren of vegetation or covered with dwarf shrub communities. Low shrub and tall shrub communities dominate the central slopes and a combination of shrub and forest is found at the lowest elevations and in the valleys. Permafrost is discontinuous (Ferrians, 1998). The Wrangell Mountains and Kluane Range ecoregions have the highest, steepest peaks in the project area (over 2800 meters) as well as extensive icefields and glaciers. These regions support populations of Dall sheep, mountain goats, brown bears, caribou, wolverines, and gray wolves (Nowacki, et al., 2002).

Figure 4. View of the Tanana-Kuskokwim Lowlands ecoregion.

Figure 5. Nutzotin Mountains of the Kluane Range ecoregion.

Wildfire plays an important role in the boreal forest and evidence of recent and historical fires is visible throughout the project area. An estimated 187,370 hectares (463,000 acres) burned within the project area between 1985 and 1999, when the imagery was acquired, including 19,957 hectares (48,327 acres) within the refuge. An additional 335,826 acres (135,904 hectares) burned between 1999 and 2005, including 39,855 acres (16,128 hectares) within the refuge during the Black Hills fire in 2003. These post-1999 burns were mapped with a second Landsat TM image acquired August 28, 2005.

5.0 Methods

5.1 Satellite Imagery and Ancillary Data

Landsat Thematic Mapper (TM) satellite imagery was chosen as the base data for this mapping project. The advantages of Landsat TM include the large regional coverage needed for a project of this scale, repeatable and standardized coverage, and seven bands of data, including Band 5 (Near-Infrared) which is particularly sensitive to both vegetation characteristics and soil moisture content and has proven useful for identifying water and wetland features.

A Landsat Thematic Mapper image from August 4, 1999 (Path 64, Row 16) served as the base data for the earth cover mapping. This image was obtained by the FWS from the MRLC (Multi-Resolution Land Characteristics) Consortium. The original image was terrain-corrected following the NLAPS protocols prior to the MRLC processing. MRLC standards require images to meet the following standards for geometric correction:

1. geometric terrain-corrected registration to within one pixel spatial accuracy;
2. data referenced to the Albers Conical Equal Area map projection (for Alaska); and
3. imagery re-sampled using cubic convolution to 30m pixels.

Following the terrain-correction, the image was converted to at-sensor reflectance as part of the MRLC processing. This reflectance image was subset to the project area and used as the source data for the Tetlin earth cover mapping (Figure 6).

A second image from the same path/row, acquired August 28, 2005, was purchased in order to map burns which occurred after the date of the 1999 image used for the base earth cover map. This image was also terrain-corrected. The projection information for both images is listed in Table 1.

Table 1. Image Projection Information

Projection: Albers Conic Equal Area
Datum: NAD83
Spheroid: GRS1980
Latitude of 1st standard parallel: 55 00 00 N
Latitude of 2nd standard parallel: 65 00 00 N
Longitude of central meridian: -154 00 00 W
Latitude of origin of projection: 50 00 00 N
False easting at central meridian: 0 meters
False northing at origin: 0 meters

Several ancillary datasets were obtained to assist in the classification process. These included a digital elevation model (DEM) and digital fire history maps from the Alaska Fire Service and from the Government of Yukon, Community Services, Protective Services Branch, Wildland Fire Management. While little of this ancillary data was utilized directly in the actual classification process, it provided valuable reference data for the analyst during this process.

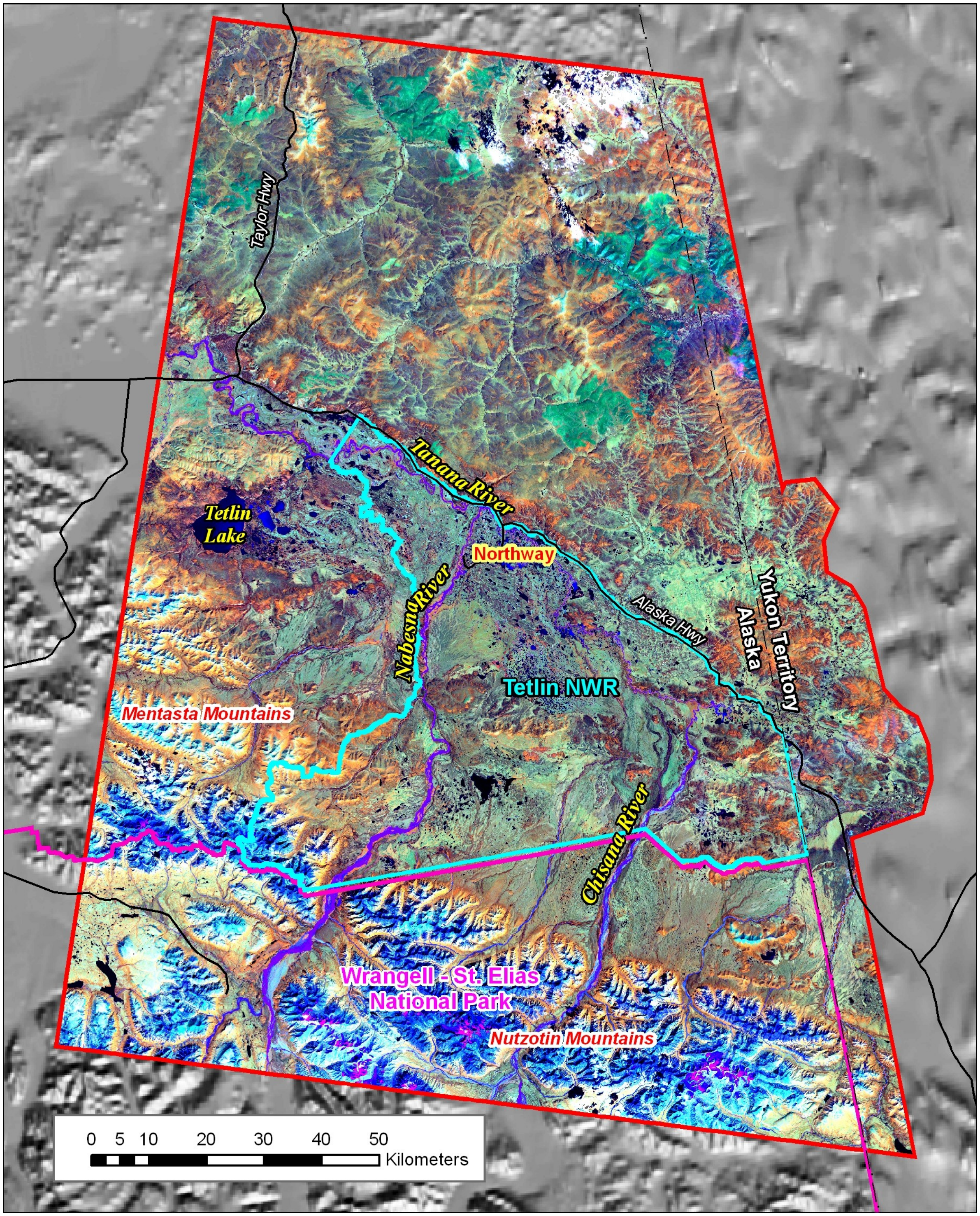


Figure 6. Landsat Thematic Mapper imagery for the Tetlin NWR/Scottie Creek project.

5.2 Sampling Design

The first step of the project was to determine the sampling design for the collection of field data to be used as training data for the classification process and reference data for assessing the accuracy of the final classified image. The sampling design consists of the following elements:

1. Classification Scheme
2. Sampling Unit
3. Number of Samples
4. Sample Selection Process

The sampling design is ultimately influenced by the detail that potentially could be derived from the source data (Landsat TM) and the overall project budget.

5.2.1 Classification Scheme

The classification scheme categorizes the features to be mapped. It is derived from the anticipated uses of the map and the features (or level of detail) that can be discerned from the source data. The classification scheme consists of two critical components: 1) a set of class labels (e.g., forest, shrub, and water); and 2) a set of rules for assigning labels. The set of rules must be mutually exclusive, such that any given area falls into only one class or label, and totally comprehensive, such that the classification scheme includes an appropriate label for every area or feature within the project area (Congalton 1991).

The Tetlin NWR/Scottie Creek classification scheme (Table 2) was based on the Alaska Earth Cover Classification developed through a cooperative partnership between the U.S. Dept. of the Interior's Bureau of Land Management and DU (Ducks Unlimited Inc., 1998). The Alaska Earth Cover Classification was adapted from the Alaska Vegetation Classification (Viereck et al., 1992) and modified for use with regional scale data sources such as Landsat TM imagery. The hierarchical nature of the classification scheme allowed specific classes to be collapsed to form more general categories when necessary. The Tetlin NWR/Scottie Creek classification scheme was slightly modified from the original Alaska classification scheme at the request of the Tetlin NWR staff to include more detailed shrub classes. Specifically, the Tall Shrub class was broken down into Tall Shrub/Willow, Tall Shrub/Alder, Tall Shrub/Willow-Alder, and Tall Shrub/Other. Additions to the Low Shrub subclasses included Low Shrub/Willow and Low Shrub/Alder.

In addition to the classification scheme, a decision tree was developed to define the rules for assigning class labels (Appendix A). With this dichotomous key, the user was guided to the one and only correct class label for a site based on the vegetation composition of the site. This provided for consistency in the labeling of field sites.

Although the Tetlin NWR/Scottie Creek classification scheme included a relatively detailed level of classes, it was anticipated that not all the observed classes could actually be mapped in the final classified image. The cost of collecting an adequate number of field sites required to map all classes at the most detailed level was beyond the budget of this project. Also, the inherent limits of the TM sensor often do not allow for this level of vegetation discrimination. Therefore, it was assumed that some of the observed classes would be "rolled up" through the hierarchical classification scheme and combined into more general mapped classes based on their spectral separability and the number of field sites collected for each class.

Table 2. Tetlin NWR / Scottie Creek Classification Scheme

1.0 Forest	3.0 Herbaceous
1.1 Closed Needleleaf	3.1 Bryoid
1.2 Open Needleleaf	3.1.1 Lichen
1.2.1 Open Needleleaf / Lichen	3.1.2 Moss
1.2.2 Open Needleleaf / Other	3.2 Wet Herbaceous
1.3 Woodland Needleleaf	3.2.1 Wet Graminoid
1.3.1 Woodland Needleleaf / Lichen	3.2.2 Wet Forb
1.3.2 Woodland Needleleaf / Other	3.3 Mesic/Dry Herbaceous
1.4 Closed Deciduous	3.3.1 Tussock Tundra
1.4.1 Closed Paper Birch	3.3.1.1 Tussock Tundra / Lichen
1.4.2 Closed Aspen	3.3.1.2 Tussock Tundra / Other
1.4.3 Closed Balsam Poplar/ Cottonwood	3.3.2 Mesic/Dry Sedge Meadow
1.4.4 Closed Mixed Deciduous	3.3.3 Mesic/Dry Grass Meadow
1.5 Open Deciduous	3.3.4 Mesic/Dry Graminoid Meadow
1.5.1 Open Paper Birch	3.3.5 Mesic/Dry Forb
1.5.2 Open Aspen	
1.5.3 Open Balsam Poplar / Cottonwood	4.0 Aquatic Vegetation
1.5.4 Open Mixed Deciduous	4.1 Aquatic Bed
1.6 Closed Mixed Needleleaf / Deciduous	4.2 Emergent Vegetation
1.7 Open Mixed Needleleaf / Deciduous	
	5.0 Water
2.0 Shrub	5.1 Clear Water
2.1 Tall Shrub	5.2 Turbid Water
2.1.1 Tall Shrub / Willow	5.3 Snow
2.1.2 Tall Shrub / Alder	5.4 Ice
2.1.3 Tall Shrub / Willow-Alder	
2.1.4 Tall Shrub / Other	6.0 Barren
2.2 Low Shrub	6.1 Sparse Vegetation
2.2.1 Low Shrub / Willow	6.2 Rock / Gravel
2.2.2 Low Shrub / Alder	6.3 Mud / Silt / Sand
2.2.3 Low Shrub / Willow-Alder	
2.2.4 Low Shrub / Tussock Tundra	7.0 Urban
2.2.5 Low Shrub / Lichen	
2.2.6 Low Shrub / Other	8.0 Agriculture
2.3 Dwarf Shrub	
2.3.1 Dwarf Shrub / Lichen	9.0 Cloud / Shadow
2.3.2 Dwarf Shrub / Other	9.1 Cloud
	9.2 Cloud Shadow
	9.3 Terrain Shadow
	10.0 Other

5.2.2 Sampling Unit

The sampling unit for a project refers to the size of the area that will be sampled in the field for use as a training or accuracy assessment site. The following criteria were established for the sampling unit:

1. Larger than the minimum mapping unit (a pixel) to minimize errors due to misregistration.
2. Could be located easily within the image using GPS technology and map interpretation.
3. Was not an arbitrary designation, i.e. formed a representative area of a cover class being mapped.

There are several potential sampling units that can be used: a pixel, a group of pixels, or a polygon. For this project, the sampling unit chosen was a homogeneous polygon, because the other possible sampling units did not satisfy all of the above criteria. For example, a random 3 X 3 cluster of pixels would be an arbitrary designation that could result in the sampling unit encompassing more than one earth cover type. Spectrally homogeneous polygons were selected because they more likely correspond to a single cover type and also provide a homogeneous spectral signature for the classification. A desired minimum size for the sites was set at 15 pixels (3.3 acres or 1.4 hectares). However meeting this minimum size was not always possible. In some cases, smaller sites were delineated in order to sample spectral classes of limited cluster sizes.

5.2.3 Sample Size

Remote sensing mapping projects recommend that an adequate number of samples be collected in the field for each earth cover class to determine the statistical validity of the classification and to provide a representative sample of the various spectral signatures of the myriad cover types for the classification. Congalton (1991) suggests 50 samples be selected for each map category as a rule of thumb. This value has been empirically derived over many projects. A second method of determining sample size includes using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to agree with Congalton's rule of thumb. However, it is often not feasible to collect 50 sites per class for a large, remote study area such as the Tetlin NWR/Scottie Creek project area. Instead sample size is influenced primarily by logistic and economic constraints.

As a compromise between statistical recommendations and more practical limitations, a minimum sample size for each earth cover class was set at 15 (5 for accuracy assessment, 10 for image processing training sites) in order to perform accuracy assessment for that class. This number was chosen in an attempt to balance the theoretical statistical recommendations and the financial limitations of large scale mapping projects.

5.2.4 Sample Selection

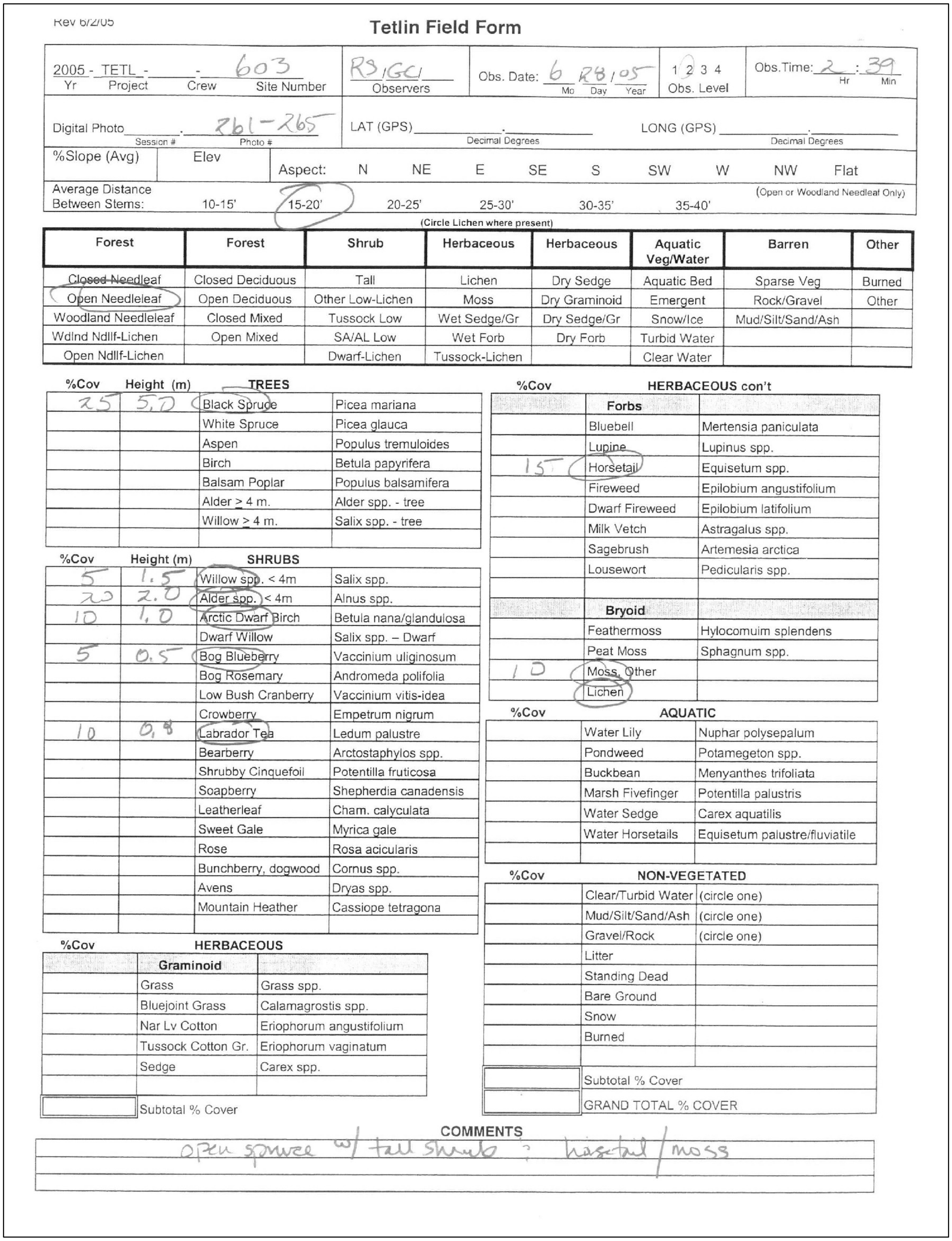
Once the appropriate sample size for the project is determined, the samples must be allocated among the earth cover classes represented in the image. The sample selection process ultimately determines the distribution of samples throughout the project. An important step in the sample selection is the approach used to select the samples. The three most common methods for selection of field sites are a random approach, a systematic approach, or a stratified approach. All of these approaches have strengths and limitations. For example, a strictly random approach has excellent statistical properties, but is difficult and expensive to apply properly. A systematic approach is easy to apply, but can result in sampling from only a subset of the spectral classes within the image, completely missing some spectral classes. And a stratified approach requires prior knowledge about the study area in order to divide the image into earth cover strata so that adequate samples can be acquired from each earth cover.

The sampling approach used in this project to select potential field sites was a stratified approach. However, since the total number and type of earth cover classes present in the image was not known prior to fieldwork, the stratification for the sample selection was based on the spectral variation found in the image. To stratify the image, a 30 class unsupervised classification was run on the image. This provided an unbiased stratification of the image into spectrally unique strata with the strata collectively representing the entire spectral variation found in the imagery.

Twenty to thirty sample sites were selected throughout the image from large, contiguous clusters of pixels ($\geq$ 15 where possible) from each of the spectral strata defined by the unsupervised classification. A polygon was hand-digitized around each site. To evaluate the spectral variation within each field site polygon and make sure it was not too broad, the standard deviation of the spectral values was calculated for each band of data. Generally, sites with a standard deviation of greater than 3 in any of the bands were not accepted. In a few cases, classes with higher standard deviations were kept due to the wide range of spectral variation found within a spectral class. In these cases, typically there were few or no areas within the class that exhibited less than three standard deviations from the spectral mean. Thus, in order to provide samples within spectral classes with a wide range of spectral variation (such as in rocky/dwarf shrub areas), higher standard deviations were allowed.

5.3 Field Preparation

After the pre-selected field sites were digitized, the coordinates of the center points of the field sites were derived from the coverage and then uploaded into a Garmin III+ GPS unit for navigational purposes. Field site polygons were laid over the satellite imagery and plotted at 1:63,360 scale (1:50,000 scale in the Canadian portion of the project area). These field maps were used for navigating to field sites, recording field notes, and placing additional field sample sites. In addition, a custom field data collection form (Figure 7) was developed to provide a means for recording and managing the field data in a reliable and consistent manner.



Rev 6/2/05

Tetlin Field Form

2005 - TETL - ___ - 603 (Yr / Project / Crew / Site Number) | RS, GC (Observers) | Obs. Date: 6 28 05 (Mo / Day / Year) | 1 2 3 4 Obs. Level | Obs.Time: 2 : 39 (Hr / Min)

Digital Photo ___ . 261-265 (Session # / Photo #) | LAT (GPS) ___ . ___ Decimal Degrees | LONG (GPS) ___ . ___ Decimal Degrees

%Slope (Avg) | Elev | Aspect: N NE E SE S SW W NW Flat

Average Distance Between Stems: 10-15' 15-20' 20-25' 25-30' 30-35' 35-40' (Open or Woodland Needleaf Only)

(Circle Lichen where present)

Forest	Forest	Shrub	Herbaceous	Herbaceous	Aquatic Veg/Water	Barren	Other
~~Closed Needleaf~~	Closed Deciduous	Tall	Lichen	Dry Sedge	Aquatic Bed	Sparse Veg	Burned
Open Needleleaf	Open Deciduous	Other Low-Lichen	Moss	Dry Graminoid	Emergent	Rock/Gravel	Other
Woodland Needleleaf	Closed Mixed	Tussock Low	Wet Sedge/Gr	Dry Sedge/Gr	Snow/Ice	Mud/Silt/Sand/Ash	
Wdlnd Ndllf-Lichen	Open Mixed	SA/AL Low	Wet Forb	Dry Forb	Turbid Water		
Open Ndllf-Lichen		Dwarf-Lichen	Tussock-Lichen		Clear Water		

TREES

%Cov	Height (m)		
25	5.0	Black Spruce	Picea mariana
		White Spruce	Picea glauca
		Aspen	Populus tremuloides
		Birch	Betula papyrifera
		Balsam Poplar	Populus balsamifera
		Alder ≥ 4 m.	Alder spp. - tree
		Willow ≥ 4 m.	Salix spp. - tree

SHRUBS

%Cov	Height (m)		
5	1.5	Willow spp. < 4m	Salix spp.
20	2.0	Alder spp. < 4m	Alnus spp.
10	1.0	Arctic Dwarf Birch	Betula nana/glandulosa
		Dwarf Willow	Salix spp. – Dwarf
5	0.5	Bog Blueberry	Vaccinium uliginosum
		Bog Rosemary	Andromeda polifolia
		Low Bush Cranberry	Vaccinium vitis-idea
		Crowberry	Empetrum nigrum
10	0.8	Labrador Tea	Ledum palustre
		Bearberry	Arctostaphylos spp.
		Shrubby Cinquefoil	Potentilla fruticosa
		Soapberry	Shepherdia canadensis
		Leatherleaf	Cham. calyculata
		Sweet Gale	Myrica gale
		Rose	Rosa acicularis
		Bunchberry, dogwood	Cornus spp.
		Avens	Dryas spp.
		Mountain Heather	Cassiope tetragona

HERBACEOUS

%Cov	Graminoid	
	Grass	Grass spp.
	Bluejoint Grass	Calamagrostis spp.
	Nar Lv Cotton	Eriophorum angustifolium
	Tussock Cotton Gr.	Eriophorum vaginatum
	Sedge	Carex spp.
	Subtotal % Cover	

HERBACEOUS con't

%Cov	Forbs	
	Bluebell	Mertensia paniculata
	Lupine	Lupinus spp.
15	Horsetail	Equisetum spp.
	Fireweed	Epilobium angustifolium
	Dwarf Fireweed	Epilobium latifolium
	Milk Vetch	Astragalus spp.
	Sagebrush	Artemesia arctica
	Lousewort	Pedicularis spp.
	Bryoid	
	Feathermoss	Hylocomuim splendens
	Peat Moss	Sphagnum spp.
10	Moss, Other	
	Lichen	

AQUATIC

%Cov		
	Water Lily	Nuphar polysepalum
	Pondweed	Potamegeton spp.
	Buckbean	Menyanthes trifoliata
	Marsh Fivefinger	Potentilla palustris
	Water Sedge	Carex aquatilis
	Water Horsetails	Equisetum palustre/fluviatile

NON-VEGETATED

%Cov		
	Clear/Turbid Water	(circle one)
	Mud/Silt/Sand/Ash	(circle one)
	Gravel/Rock	(circle one)
	Litter	
	Standing Dead	
	Bare Ground	
	Snow	
	Burned	
	Subtotal % Cover	
	GRAND TOTAL % COVER	

COMMENTS

open spruce w/ tall shrubs ? horsetail / moss

Figure 7. Example field data collection form.

5.4 Field Data Collection

Field data was collected from June 19 – June 29, 2005. The objective of the field data collection was to assess, measure, and document the on-the-ground earth cover variation within the project area. Due to the remote nature of the project area, the field data was collected via helicopter (Robinson R44). Working from a helicopter not only allowed access to remote areas, but also provided the crew with an orthogonal view of the project area, similar to that recorded by the satellite sensor. Fieldwork was staged out of Northway, AK. Approximately 43 hrs were flown over the combined project area, with an average of 5.8 hrs flown per day. One day of flight time (approximately 5 hours) was devoted to the Scottie Creek portion of the project area. Approximately four days of field time were lost due to mechanical repairs to the helicopter. Field data collection in the Wrangell-St. Elias NP portion of the project area took place under a Scientific Research and Collecting Permit (Permit #WRST-2005-SCI-0010) issued by the National Park Service.

A four person crew performed the field data collection. The crew consisted of the pilot, biologist, navigator, and a biological technician who entered the field data. The biologist was a member of the Tetlin NWR staff and thus had extensive knowledge of the project area. The image analyst for the project served as the navigator and thus was able to gain valuable first-hand knowledge of the project area. This site-specific experience greatly aided the analyst in classifying the imagery and contributed to a higher quality end product.

The navigator selected the sites to visit and guided the pilot to each site using a GPS uploaded with coordinates for the pre-selected sites and fieldmaps. As the helicopter approached a site, the navigator described the site boundaries to the biologist and a high overhead picture of the site was taken with the digital camera. Once the site was defined, the pilot took the helicopter down to approximately 5-10 meters above the vegetation and flew laterally across the site while the biologist identified and recorded the vegetation composition on a standardized fieldform. A close-up photograph of the site was taken at this low level. Then the pilot ascended to approximately 50-100 meters above the site and the biologist estimated the percent coverage of each observed species and determined the overall earth cover class based on the decision tree. Additional photographs were taken from this altitude, including context photos. On average, approximately 5-8 minutes were spent at each site collecting data. The majority of sites were surveyed from the air. Ground verification was performed when identification of dominant vegetation was uncertain and landing conditions permitted. The biological technician was responsible for on-ground support and data entry.

A total of 397 field sites were visited in the field, including 142 within Tetlin NWR, 54 in Wrangell-St. Elias NP, and 31 within the Scottie Creek portion of the project area (Figure 8). These sites represented 36 different earth cover classes as defined by the classification scheme (Table 3).

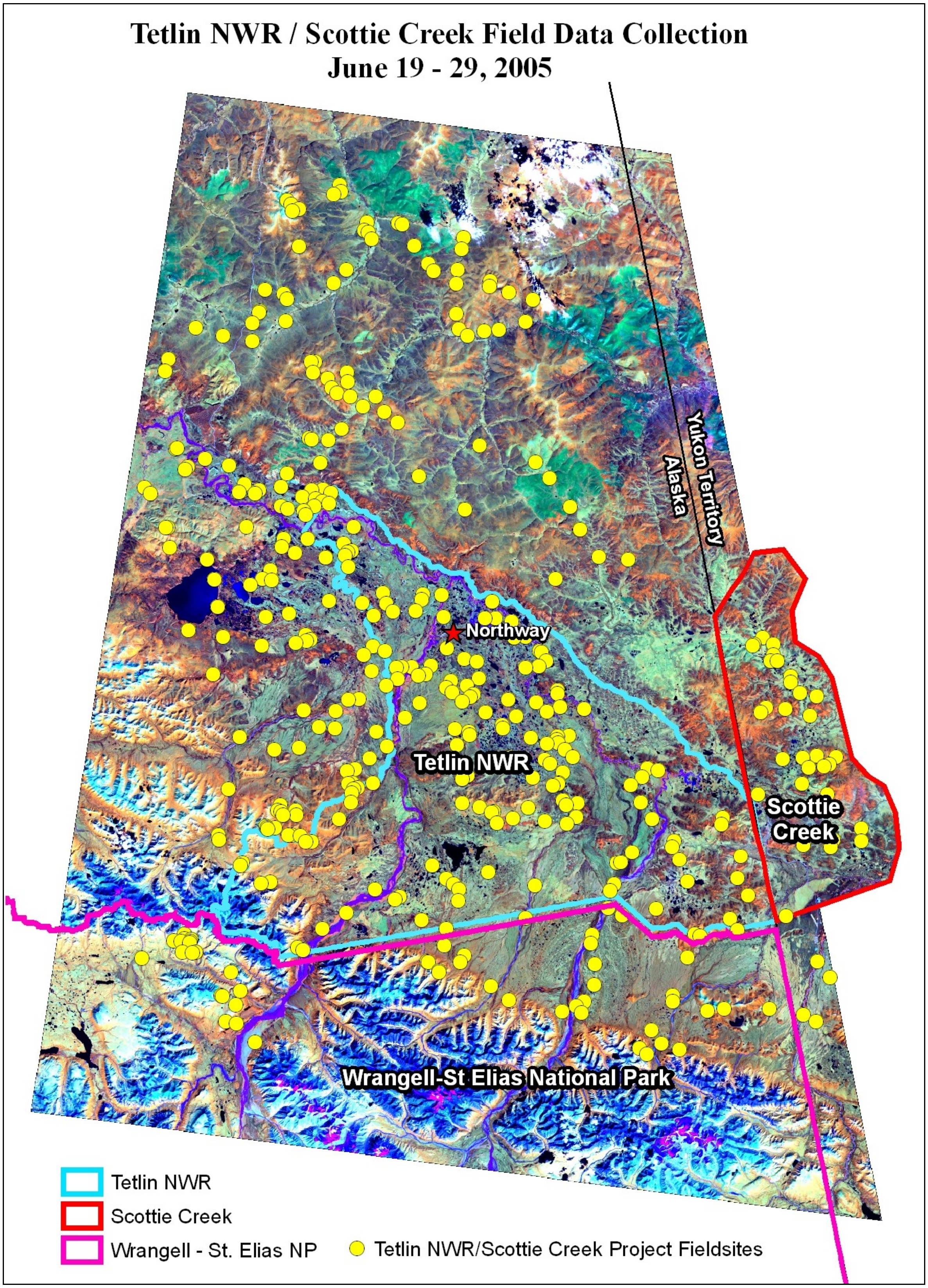


Figure 8. Field sites and staging area for the Tetlin NWR / Scottie Creek project.

Table 3. Summary of Field Sites.

Class	# Total Sites
Closed Needleleaf	16
Open Needleleaf	
Open Needleleaf / Lichen	13
Open Needleleaf / Other	56
Closed Deciduous	
Closed Aspen	8
Closed Birch	18
Closed Poplar	4
Closed Mixed Deciduous	15
Open Deciduous	
Open Aspen	1
Open Birch	2
Open Poplar	3
Open Mixed Deciduous	6
Closed Mixed Needleleaf / Deciduous	13
Open Mixed Needleleaf / Deciduous	11
Woodland Needleleaf	
Woodland Needleleaf / Lichen	3
Woodland Needleleaf / Other	30
Tall Shrub	
Tall Shrub / Willow	6
Tall Shrub / Alder	5
Tall Shrub / Willow-Alder	7
Tall Shrub / Other	8
Low Shrub	
Low Shrub / Willow	10
Low Shrub / Alder	
Low Shrub / Willow-Alder	
Low Shrub / Tussock Tundra	8
Low Shrub / Lichen	1
Low Shrub / Other	56
Dwarf Shrub	
Dwarf Shrub / Lichen	2
Dwarf Shrub / Other	21

Class	# Total Sites
Bryoid	
Lichen	
Moss	5
Herbaceous	
Wet Herbaceous	
Wet Graminoid	18
Wet Forb	
Mesic/Dry Herbaceous	
Mesic/Dry Graminoid	
Mesic/Dry Sedge Meadow	
Mesic/Dry Grass Meadow	
Mesic/Dry Forb	2
Tussock Tundra	
Tussock Tundra / Lichen	
Tussock Tundra / Other	8
Aquatic Vegetation	
Aquatic Bed	10
Emergent Vegetation	18
Water	
Clear Water	1
Turbid Water	
Barren	
Sparse Vegetation	1
Rock/Gravel	3
Non-Vegetated Soil	1
Urban	
Agriculture	
Snow	
Ice	
Cloud/Haze	
Cloud Shadow	
Terrain Shadow	
Other	7
Total	**397**

The final number of samples for each earth cover class was generally a reflection of the proportion of that earth cover within the project area, although some earth covers (e.g. the wetland classes) were given more attention due to their inherent variability. Thus, if one class covered a larger proportion of the project area than another class, more field sites were obtained for that class. Exceptions to this rule were for classes such as clear water, shadow, ice, snow, and urban, which, due to the inherent spectral and contextual properties, were easily determined from the imagery and therefore were not sampled in the field. Other earth cover classes were naturally limited in size and distribution, thus the minimum sample size could not be obtained.

The field data was entered into a digital database using a custom data entry application known as DUFF (for "Ducks Unlimited Field Form") that was designed jointly by the Bureau of Land Management and DU Inc. and programmed by GeoNorth. The application consisted of a relational database powered by Microsoft Access and an interface programmed in Visual Basic. The user interface was organized similarly to the field form to facilitate data entry (Figure 9). The application utilized pull down menus to minimize keystrokes and checked for data integrity to minimize data entry errors. The database program also determined the "calculated class" (class label) for each site based on the decision tree which was programmed into the application. This served as a proofing mechanism to help minimize the potential for human error in calculating the class labels. Digital photographs from each site were stored in the database and were accessible from within the user interface. The number of field sites per earth cover class was tallied daily to ensure that adequate samples were being obtained for each class.

5.5 Selection of Training and Accuracy Assessment Sites

Following the field collection, the field data was checked for consistency and accurate data entry, and the pro-actively selected field sites were digitized. The sites were tallied by earth cover class and an evaluation was made as to which classes (either individual classes or rolled-up classes) had enough sites to allow for accuracy assessment. A minimum of 15 sites was required for an individual class before any attempt was made to assess the accuracy of that class. This allowed for a minimum of 10 sites for training and 5 sites for accuracy assessment. Fewer than five sites for accuracy assessment were considered too few to provide a meaningful assessment. Therefore, accuracy assessment was not performed for classes with fewer than 15 sites.

Classes with fewer than 15 sites were rolled-up or combined with other classes when possible to produce enough sites to perform accuracy assessment at a more generalized level of the classification scheme. For example, none of the species-specific closed deciduous classes (Closed Aspen, Closed Birch, Closed Poplar, Closed Mixed Deciduous) had enough sites for an individual accuracy assessment. Instead, these sites were rolled-up into a generalized Closed Deciduous class for accuracy assessment, with sites contributed from the species-specific classes.

Sample Field Site – Closed Mixed Needleleaf/Deciduous

High Site Photo

Low Site Photo

DUFF INTERFACE

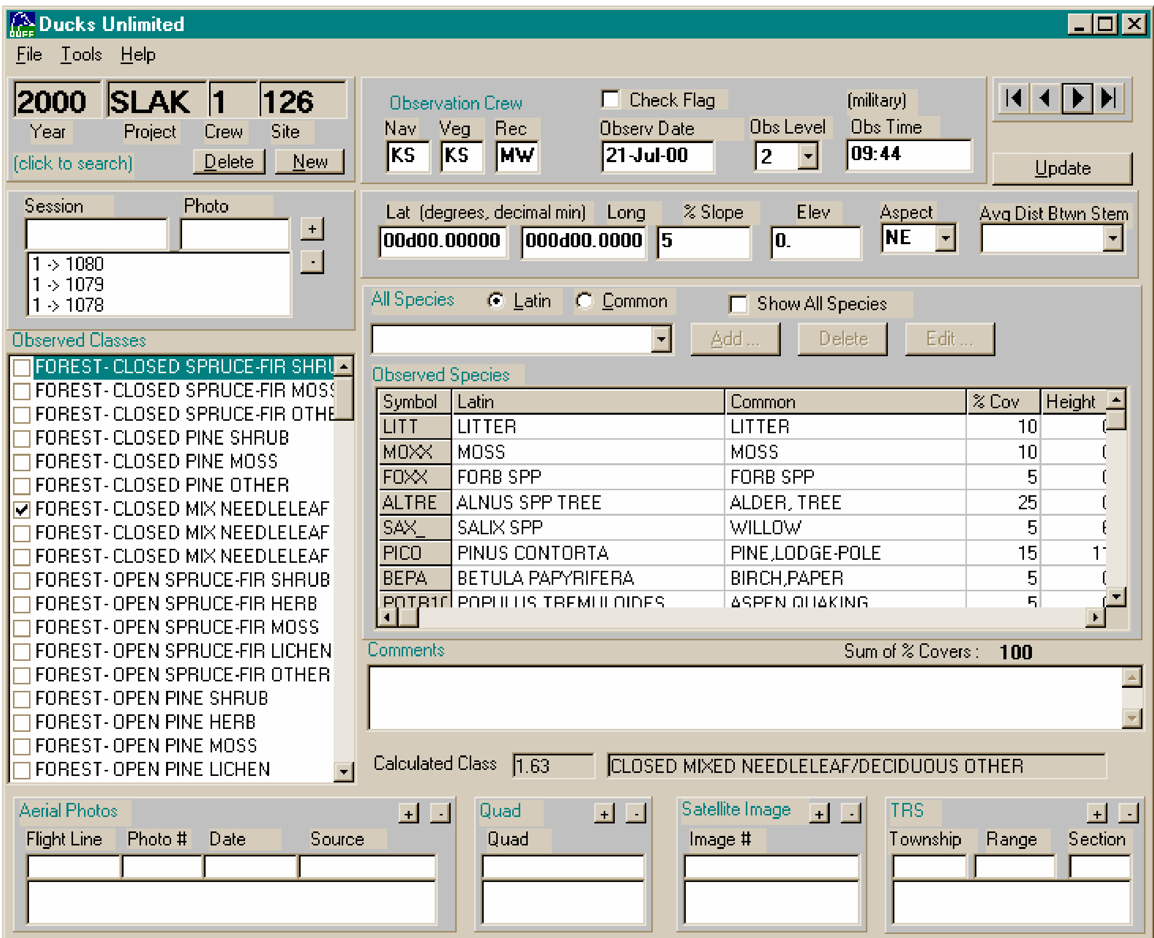


Figure 9. The customized database and user interface for field data entry (DUFF).

The accuracy assessment sites were selected from the field sites using a stratified random approach. First, the field sites were stratified by class (individual or rolled-up classes). Then approximately a third of the sites within each class were randomly selected and set aside for accuracy assessment. In all, 94 of the 397 visited field sites were set aside for accuracy assessment while the remaining sites were utilized in the classification process as training data.

5.6 Classification

Three primary software packages were used for the image analysis. Erdas Imagine 8.7 was used for the basic image processing tasks, such as subsetting and creating new data layers. It was also used to help classify some of the basic classes, such as water and rock/gravel. ESRI ARCGIS 9.0 was used to handle the GIS coverages and other ancillary datasets. The bulk of the image classification process was done using Definien's Professional 4 (eCognition) software which uses an object-based approach to image classification. An image object is a group of contiguous pixels grouped together based on heterogeneity criteria and a user-specified parameter of scale. The use of eCognition software for image classification offered a number of advantages: 1) it allows for the processing of imagery datasets using a region-based approach; 2) it utilizes parameters such as shape, color, texture, and contextual information to aid in classification; and 3) it allows for the development and use of a knowledge base for the classification.

5.6.1 Generation of New Bands

In preparation for image classification, the thermal band was removed from each of the Landsat TM images, leaving a composite image consisting of TM bands 1-5 and 7. A three-band Principal Components image and a Tasseled-Cap (Crist and Cicone, 1984) brightness/greenness/wetness image were generated from each 6 band TM subset. These images were then clipped to the project area and used as additional data for the classification process.

5.6.2 Segmentation

The first step in the classification procedure involved segmenting the 1999 TM imagery into distinct regions known as image objects using eCognition software. The image objects are groups of pixels formed into a region based on a set of heterogeneity criteria (scale parameters, color, shape, smoothness, compactness). The overall goal of the segmentation process was to create image objects that were as large as possible but as small as necessary to discriminate and map the earth cover features (Definiens Imaging, 2004).

For image classification, the six-band TM image subset was added to an eCognition project along with the three-band principal components image and the tasseled-cap brightness/greenness/wetness image. The imagery was then segmented at several different scales. Scale 2.5 was chosen as the segmentation scale for the detailed classification because the resulting image objects provided good discrimination of spectral differences between and within earth cover types, yet was not so fine as to result in a high proportion of single pixel objects. The second segmentation was performed at scale 5. This segmentation grouped the initial objects from the scale 2.5 segmentation into larger, coarser objects that could be used to break out general landcover classes as a first step in the classification process. The segmentations were performed with only the TM image layers as input. Examples of the image objects from each scale are shown in Figure 10.

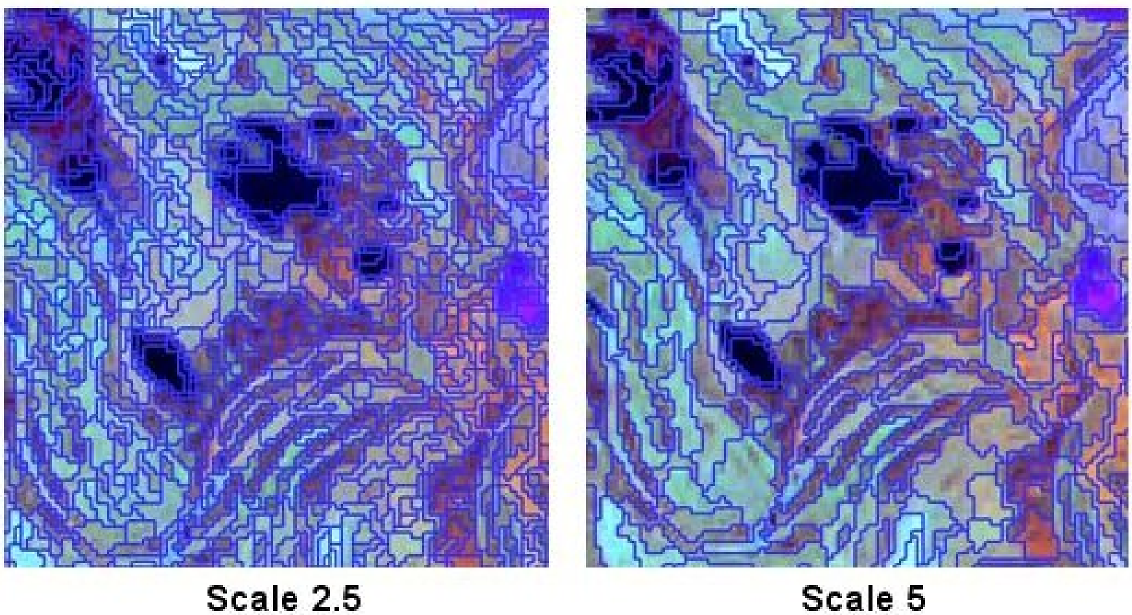


Figure 10. Examples of image objects at scale 2.5 and scale 5.

Additional segmentations were performed at higher scales, such as scale 15 and scale 30 to classify clouds and cloud shadows and to create super-object masks for refining the classification of the general classes at scale 5.

5.6.3 Earth Cover Classification

Using eCognition software, the image-objects created by the segmentation procedure were classified. The classification process used a combination of rule based classification (via user-defined membership functions) and a supervised nearest-neighbor classification approach. The use of both of these techniques allowed for more flexibility in the classification process.

An overall 3-level hierarchical approach was applied in which general earth cover classes were defined at coarser scales of segmentation and more detailed classes defined at a finer scale. As a first step clouds, cloud shadows, recent burns, and regenerating burn areas were defined at Level 3 using a very coarse segmentation scale, such as a scale of 15 or 30. These objects were defined using membership functions in which strict parameters or rules were applied to classify the image objects. Manual editing was performed as needed to refine these classes. The regenerating burn areas were mapped out at this level to serve as a mask at lower-scale levels where the spectral signatures of regenerating earth covers tend to be confused with other earth cover classes in the non-burned areas. For example, regenerating low shrub is often spectrally similar to mature closed or open deciduous.

The clouds, cloud shadows, recent burns, and regenerating burns were then passed down to the intermediate scale of segmentation (scale 5) or hierarchy Level 2. This was done by defining membership functions at Level 2 that referred to the objects classified in the previous level of segmentation (Level 3), known as super-objects. Once this was done, the remaining image objects were classified at this intermediate scale into general earth cover classes such as needleleaf forest, deciduous forest, shrubs, etc. Membership functions were used to define some of the general classes that were spectrally distinct (i.e. little spectral overlap with other classes), such as Water/Aquatic Wetlands and Rock/Gravel. The rest of the major classes were defined using supervised classification techniques.

An effort was made to identify membership functions that would effectively separate additional major earth cover classes at the intermediate scale (Level 2), but after many trials it was determined that nearest-neighbor classification techniques did a better job of separating out the various general vegetation classes. This was largely due to the fact that there is considerable spectral overlap between many of the vegetated earth cover types in the project area which made it difficult to find simple membership functions that would adequately separate them. The supervised classification technique, which uses multiple image bands, gave better results, requiring less refinement at the detailed level of segmentation.

Once the Level 2 mapping of general classes was completed, these classes were passed down to Level 1 and were further refined as needed. For example, the Deciduous general class from Level 2 was broken down into Closed Deciduous - General, Open Deciduous - General, Closed Aspen, Open Aspen, Tall Shrub, and Mixed Needleleaf/Deciduous classes at Level 1. Supervised classification techniques were used to define most of the detailed classes at Level 1. Figure 11 shows an idealized example of a classification hierarchy used for the project. In reality, there was often more confusion within the general classes, resulting in more duplication in the detailed earth cover classes broken out under the various general classes at Level 1.

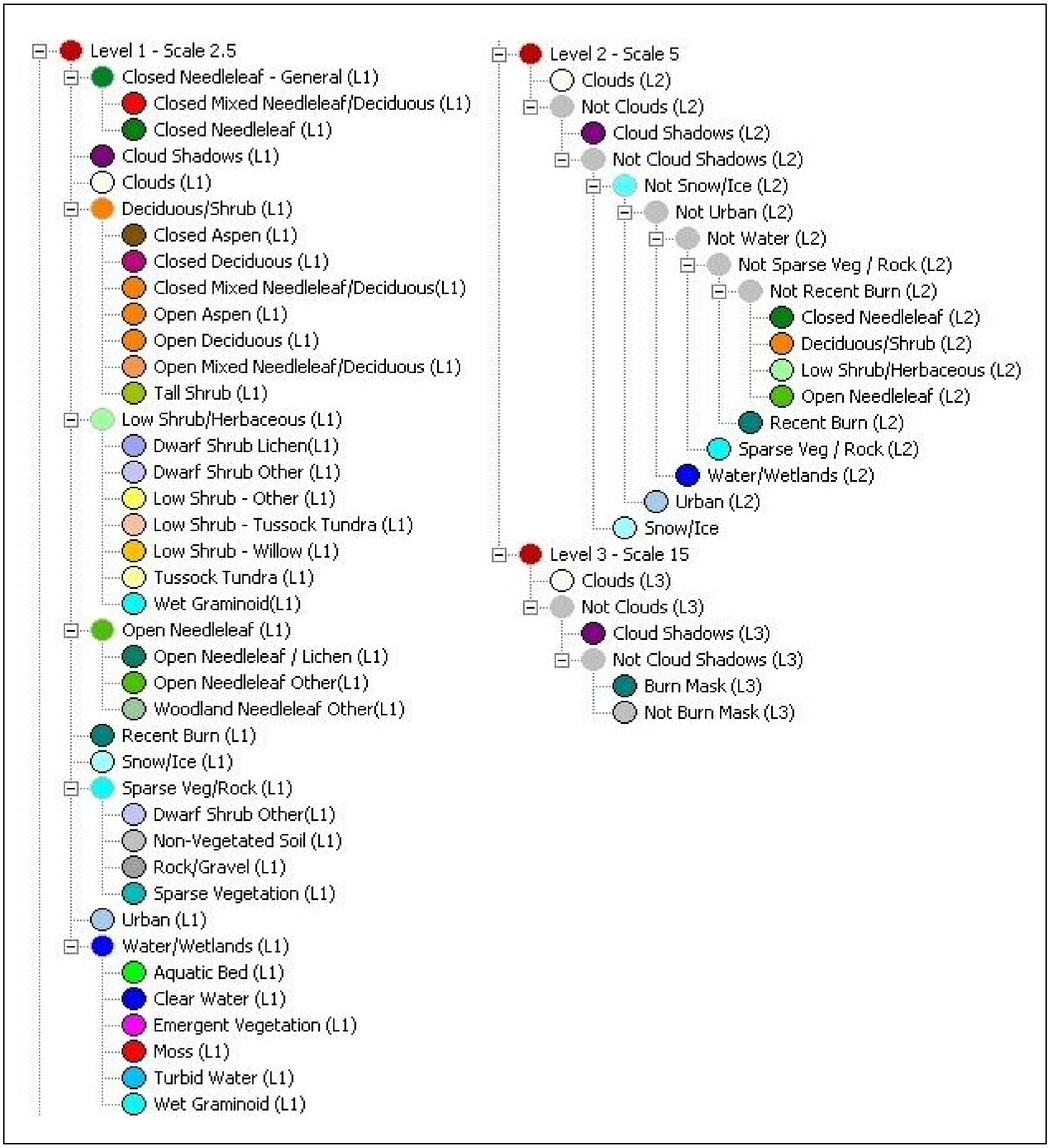


Figure 11. Typical classification hierarchy used for the Tetlin NWR/Scottie Creek project.

5.7 Accuracy Assessment

The accuracy assessment procedure compares the map with reference data to estimate the accuracy of the final map. There are two primary motivations for accuracy assessment: (1) to understand the errors in the map (so they can be corrected), and (2) to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992).

The accuracy was calculated for each of the designated accuracy assessment sites by comparing the mapped class (or classes) of the pixels within each accuracy assessment site with the site's reference class designation derived from the field data. If the majority map class within the accuracy assessment site corresponded to the earth cover class label from the field data, the site was considered correct or "true." Conversely, if the majority map class within the accuracy assessment site differed from the field data class, the site was considered incorrectly classified or "false." After each site was evaluated against the reference data, the overall map accuracy was calculated by determining the percentage of all the accuracy assessment sites that were correctly classified.

A major assumption of quantitative accuracy assessments is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation errors (Congalton and Green, 1993). Unfortunately, quantitative accuracy assessments can be inadequate indicators of map error because they often reflect non-map errors. Some of the non-map errors that can cause confusion are: registration differences between the reference data and the remotely sensed map classification, digitizing errors, data entry errors, changes in earth cover between the date of the remotely sensed data and the date of the reference data, mistakes in interpretation of reference data, and variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation.

In an effort to account for some of the variation in human interpretation, overall classification accuracies were generated allowing for a +/- 5% variation in estimation of species composition for each of the accuracy assessment sites. In other words, if a variation in interpretation of +/- 5% for a particular species would have resulted in the generation of a different reference site label, this new label was also considered an acceptable mapping label for the reference site. This is known as "fuzzy" logic. For example, at field site #231 the biologist interpreted the site to contain 60% spruce cover resulting in a Closed Needleleaf label for the site. In the final classified map the majority of the site was classified as Open Needleleaf Other, making it incorrectly classified in the original accuracy assessment. But with a +5% change in the percentage of tree cover, the field site would have been labeled Open Spruce Other and therefore it would have been considered acceptably classified using fuzzy logic. This method of accuracy assessment allows the user to evaluate and measure the relationship between sites that classify nicely into the "heart" of the mapping class and those regions that occur on the spectral and ecological boundaries between the discrete mapping classes. Evaluating the earth cover classification in this manner provides the end user with a more realistic measure of the reliability of the classified map as it relates to the actual continuum of vegetation composition.

While the accuracy assessment performed in this project was not a robust test of the classification because of the limited number of accuracy sample sites, it gives the user some sense of confidence in using the classification. It also provided enough detail for the end user to determine where discrepancies in the classification may cause problems when using the data.

5.7.1 Error Matrix

An effective way to present accuracy assessment results is to produce an error matrix (Table 5), also known as a confusion matrix, or contingency table. An error matrix allows the user to understand the accuracies of individual classes as well as the types of errors present in the classification. The matrix is designed as a square array with the columns representing the reference data and the rows representing the classification (Lillesand and Kiefer, 1994). The numbers within the array express the number of sites assigned to a particular class in the reference data relative to the number of sites mapped to a particular class in the classification. Numbers along the main diagonal of the matrix (yellow cells in Table 4) indicate an exact match between the reference data site and the map (i.e. correctly classified accuracy assessment sites). Sites that have been designated as "false" in the accuracy assessment are shown in the off-diagonal cells of the error matrix. Overall accuracy is calculated as the sum of the major diagonal cells (i.e., the correctly classified samples) divided by the total number of samples in the error matrix.

Table 4. Error matrix example with +/- 0% variation in interpretation.

Classified Data	Reference Data: Conifer	Deciduous	Shrub	Herbaceous	*Row Total*	**User's Acc.**
Conifer	28				28	100%
Deciduous	2	10	4		16	63%
Shrub		4	13	2	19	68%
Herbaceous		1	3	8	12	67%
Column Total	30	15	20	10	75	
Producer's Acc.	93%	67%	65%	80%		79%

Overall Accuracy = (28 + 10 + 13 + 8) / 75 = 79%

	Producer's Accuracy	User's Accuracy
Conifer	28 / 30 = 93%	28 / 28 = 100%
Deciduous	10 / 15 = 67%	10 / 16 = 63%
Shrub	13 / 20 = 65%	13 / 19 = 68%
Herbaceous	8 / 10 = 80%	8 / 12 =67%

Errors of omission (exclusion) and errors of commission (inclusion) are both indicated in the matrix. An omission error occurs when a reference area (or accuracy assessment site) is incorrectly mapped to a category to which it does not actually belong, or in other words, is omitted from the correct map category. These are represented for the individual earth cover classes as the off-diagonal cells in the column under a particular earth cover reference class. Errors of omission are measured as the Producer's Accuracy which is calculated as the total number of reference sites correctly classified as a particular earth cover class divided by the total number of reference sites (column total) with that particular earth cover class label.

A commission error occurs when a map class incorrectly includes a reference site that does not belong to that class. These are indicated for a particular map class in the off-diagonal cells along a row. Errors of commission are reported as the User's Accuracy which is calculated as the total number of sites correctly classified as a particular earth cover class divided by the total number of sites classified as that earth cover class (row total) (Story and Congalton, 1986; Congalton and Green, 1993). Every error is an omission from the correct category and a commission to a wrong category. Producer's and user's accuracies are ways of representing the accuracy of individual earth cover classes in the final classified map.

When +/- 5% variation in interpretation is allowed, the off-diagonal numbers are represented as follows: (a,b) where a = number of acceptable sites with +/5 % variation and b=number of "false" or incorrect sites with +/- 5% variation. For example, in Table 5 there were four shrub reference sites that were mapped as deciduous (refer to the numbers in red). Of these four sites, one was considered acceptably classified given a +/- 5% variation in interpretation of the species composition within the site. Thus, when calculating the Producer's accuracy, 14 sites are considered correctly classified, resulting in a Producer's accuracy of 70% for the shrub class (compared to 65% Producer's accuracy for the shrub class in Table 4 where no fuzzy logic was applied).

Table 5. Error matrix example with +/- 5% variation in interpretation.

		Reference Data					
		Conifer	Deciduous	Shrub	Herbaceous	*Row Total*	**User's Acc.+/- 5%**
Map Data	Conifer	28				28	100%
	Deciduous	(0,2)	10	(1,3)		16	69%
	Shrub		(2,2)	13	(0,2)	19	79%
	Herbaceous		(0,1)	(0,3)	8	12	67%
	Column Total	30	15	20	10	75	
	Producer's Acc.+/- 5%	93%	80%	70%	80%		**83%**

Overall Accuracy = (28 + 10 + 2 + 1 + 13 + 8) / 75 = 83%

	Producer's Accuracy	User's Accuracy
Conifer	28 / 30 = 93%	28 / 28 = 100%
Deciduous	(10+2)/15 = 80%	(10+1)/16 = 69%
Shrub	(13+1)/20 = 70%	(13+2)/19 = 79%
Herbaceous	8 / 10 = 80%	(8+1)/12 =67%

5.8 Post-1999 Burn Mapping

The August 2005 TM image was segmented at a coarse scale and the general boundaries of the post-1999 burns were delineated by manual classification. These areas were then segmented at finer scales and the boundaries of the burns were refined. Once the boundaries were established, the interior of the burns were classified to identify the unburned inclusions and areas of regenerating vegetation. The Normalized Burn Ratio (Lutes et al. 2006) was calculated for the image objects as follows:

$$NBR = \frac{TM\ band\ 4 - TM\ band\ 7}{TM\ band\ 4 + TM\ band\ 7}$$

A threshold NBR value was then determined to separate burned areas with little or no live vegetation from unburned or revegetated areas. The unburned/revegetated areas were then classified into several general classes using membership functions, nearest neighbor supervised classification methods, and some manual editing.

6.0 Results

6.1 Earth Cover Classification

A total of 34 earth cover classes were mapped in the final earth cover map (Figure 12), including clouds, cloud shadows, and smoke/haze that were present on the date of the image acquisition. Table 6 presents a breakdown of the area covered by each class within the full project area and Table 7 presents the same statistics for the earth covers within Tetlin NWR legal boundary. A description of each of the classes is provided in Appendix C. The three most extensive vegetation classes within the final classification were Open Spruce Other (32.6%), Woodland Needleleaf Other (11.8%), and Low Shrub Other (11.5%). Rock/Gravel, which covered much of the Wrangell Mountains was close behind Low Shrub Other with 9.1%. This breakdown agrees with observations made during the field data collection.

6.1.1 Forested Cover Types

Nearly two-thirds (58%) of the Tetlin NWR/Scottie Creek project area was mapped as forest (Figure 13): 50% needleleaf forest, 4% deciduous forest, and 4% mixed forest. All of the needleleaf forest consisted of black spruce (*Picea mariana*), white spruce (*P. glauca*) or mixtures of the two. No other needleleaf species was observed during fieldwork. In areas of better soils or drainage (e.g. on slopes or alluvial soils), the spruce tended to be more robust and dense. At lower elevations or in areas of poor drainage and soils, the spruce (primarily black spruce) was often stunted and had a more open canopy. Closed Needleleaf forest made up only 4.9% of the project area. The open needleleaf forest was mapped as Open Needleleaf Other (32.6%) and Open Needleleaf Lichen (.6%).

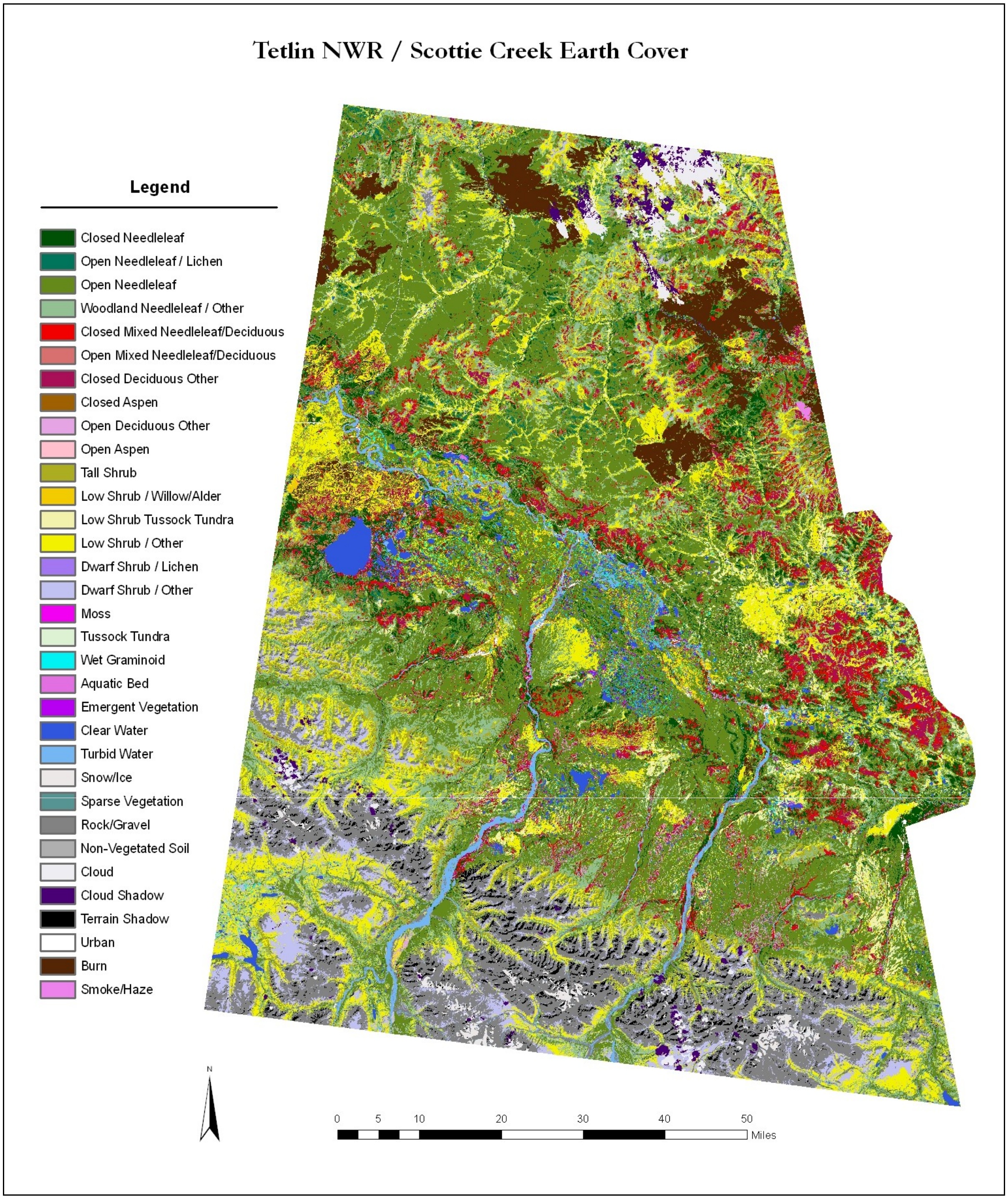


Figure 12. Tetlin NWR / Scottie Creek earth cover map.

Table 6. Area covered and percent cover of earth cover classes within the project area.

Class	Acres	Hectares	% of Area
Closed Needleleaf	265,029	107,253	4.91%
Open Needleleaf / Lichen	33,299	13,475	0.62%
Open Needleleaf / Other	1,759,818	712,173	32.61%
Woodland Needleleaf / Other	638,472	258,380	11.83%
Closed Mixed Needleleaf/Deciduous	191,646	77,556	3.55%
Open Mixed Needleleaf/Deciduous	40,229	16,280	0.75%
Closed Deciduous - General	150,297	60,823	2.79%
Closed Aspen	19,811	8,017	0.37%
Open Deciduous - General	36,864	14,918	0.68%
Open Aspen	28	12	0.00%
Tall Shrub - General	235,092	95,138	4.36%
Low Shrub - Willow	22,125	8,954	0.41%
Low Shrub - Tussock Tundra	101,419	41,043	1.88%
Low Shrub - Other	621,328	251,442	11.51%
Dwarf Shrub - Lichen	143	58	0.00%
Dwarf Shrub Other	220,207	89,115	4.08%
Moss	2,682	1,085	0.05%
Tussock Tundra	495	200	0.01%
Wet Graminoid	37,713	15,262	0.70%
Aquatic Bed	5,965	2,414	0.11%
Emergent Vegetation	16,240	6,572	0.30%
Clear Water	84,736	34,291	1.57%
Turbid Water	62,275	25,202	1.15%
Snow/Ice	23,382	9,462	0.43%
Sparse Vegetation	1,589	643	0.03%
Rock/Gravel	490,580	198,530	9.09%
Non-Vegetated Soil	837	339	0.02%
Cloud	53,609	21,695	0.99%
Cloud Shadow	35,116	14,211	0.65%
Terrain Shadow	63,508	25,701	1.18%
Urban	7,283	2,947	0.13%
Recent Burn	172,928	69,982	3.20%
Smoke/Haze	1,347	545	0.02%
Total	**5,396,090**	**2,183,719**	**100.00%**

Table 7. Area covered and percent cover of earth cover classes within Tetlin NWR.

Class	Acres	Hectares	% of Area
Closed Needleleaf	67,615	27,363	7.25%
Open Needleleaf / Lichen	277	112	0.03%
Open Needleleaf / Other	428,074	173,235	45.90%
Woodland Needleleaf / Other	70,734	28,625	7.58%
Closed Mixed Needleleaf/Deciduous	35,417	14,333	3.80%
Open Mixed Needleleaf/Deciduous	4,797	1,941	0.51%
Closed Deciduous - General	27,660	11,194	2.97%
Closed Aspen	415	168	0.04%
Open Deciduous - General	12,440	5,034	1.33%
Tall Shrub - General	38,067	15,405	4.08%
Low Shrub - Willow	11,019	4,459	1.18%
Low Shrub - Tussock Tundra	29,420	11,906	3.15%
Low Shrub - Other	77,847	31,504	8.35%
Dwarf Shrub Other	6,127	2,480	0.66%
Moss	1,534	621	0.16%
Tussock Tundra	0.4	0.2	0.00%
Wet Graminoid	21,757	8,805	2.33%
Aquatic Bed	3,519	1,424	0.38%
Emergent Vegetation	10,253	4,149	1.10%
Clear Water	32,589	13,188	3.49%
Turbid Water	26,356	10,666	2.83%
Snow/Ice	362	146	0.04%
Sparse Vegetation	10	4	0.00%
Rock/Gravel	19,204	7,772	2.06%
Non-Vegetated Soil	350	142	0.04%
Cloud	406	164	0.04%
Cloud Shadow	243	98	0.03%
Terrain Shadow	3,643	1,474	0.39%
Urban	617	250	0.07%
Recent Burn	1,955	791	0.21%
Total	**932,707**	**377,453**	**100.00%**

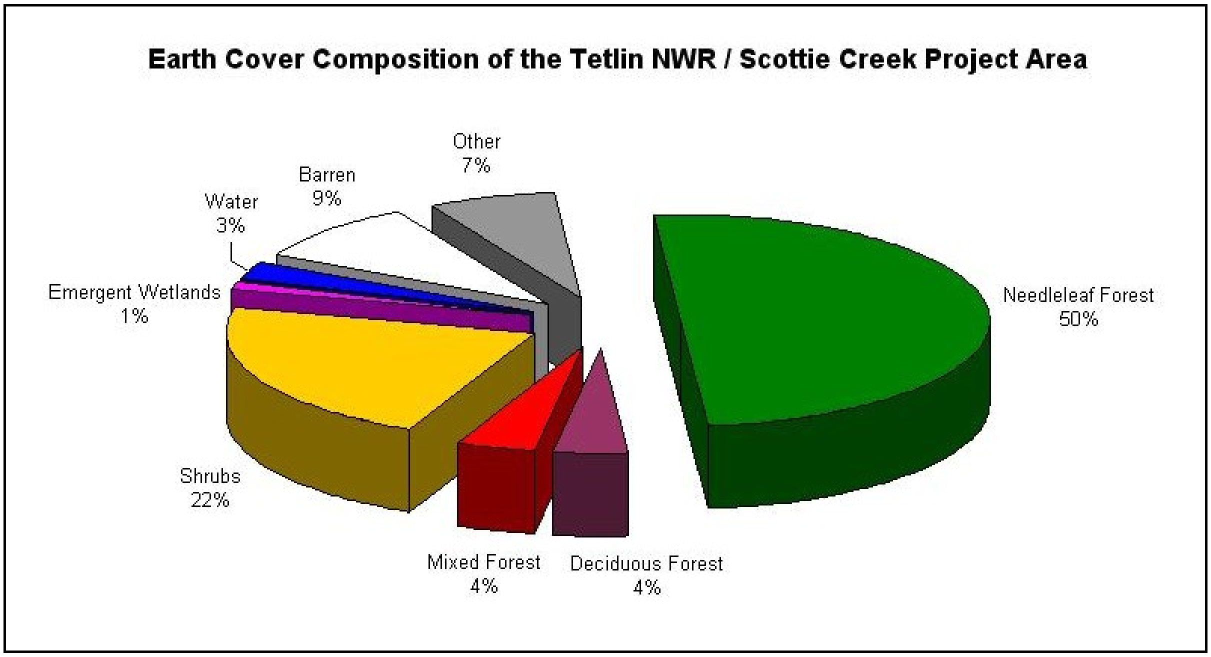


Figure 13. Percentages of the major earth cover types in the Tetlin NWR / Scottie Creek project area.

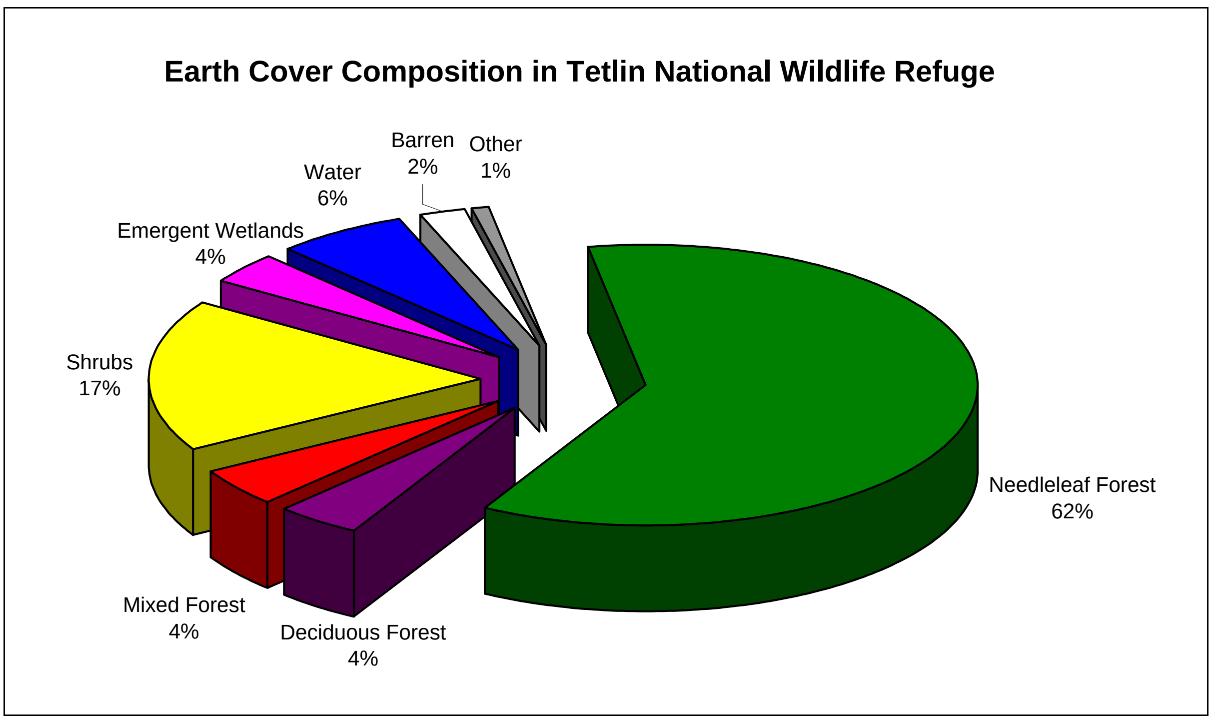


Figure 14. Percentage of the major earth cover types within Tetlin National Wildlife Refuge.

Nine of the thirteen open needleleaf lichen field sites were located on the lower slopes of hills, mostly north of the Alaska Highway or in the Scottie Creek area. Four sites were in the lowlands: two between Wellesley Mountain and the Nutzotin Mountains just south of the Tetlin NWR boundary and one just northeast of Wellesley Mountain within the refuge. The fourth site, also in the refuge, was in a broad valley leading from the lowlands into the Mentasta Mountains. These lowland open needleleaf lichen sites did not have a distinctive signature and could not be separated from surrounding open needleleaf other. It’s not clear why the lichen was so difficult to discern in these lowland areas. It’s possible the lichen was confused with the dry litter from tussocks which were found in much of the nearby open needleleaf other and therefore did not stand out as distinct. The open needleleaf lichen in the hills was easier to discern and was mapped. However, in sites with denser tree canopies (>50%), the lichen was difficult to detect and was not always mapped successfully. In trying to pull in these areas it is likely that some areas of open needleleaf other were incorrectly included in the open needleleaf lichen map class.

The woodland needleleaf forest consisted of two types found in different environments. In the lowlands, most of the woodland forest was characterized by sparse, stunted black spruce and an understory dominated by tussock sedges with a mix of bog birch, willow, and some moss (Figure 15). At higher elevations with better drainage, the woodland spruce (often white spruce) tended to be taller and more robust with a relatively lush understory dominated by low shrub bog birch or taller willow and alder shrubs, thus giving it a very different signature than the lowland woodlands. Where tall shrubs dominated the understory, the woodland signature could be confused with that of tall shrub, open or closed deciduous, or open mixed needleleaf/deciduous.

Although three Woodland Needleleaf Lichen sites were visited in the field, this class was not mapped because a clear spectral signature could not be established. Instead it was incorporated into the Woodland Needleleaf Other class. Field observations indicate that this class was not extensive in the project area, occurring as small, isolated patches with relatively low percentages of lichen.

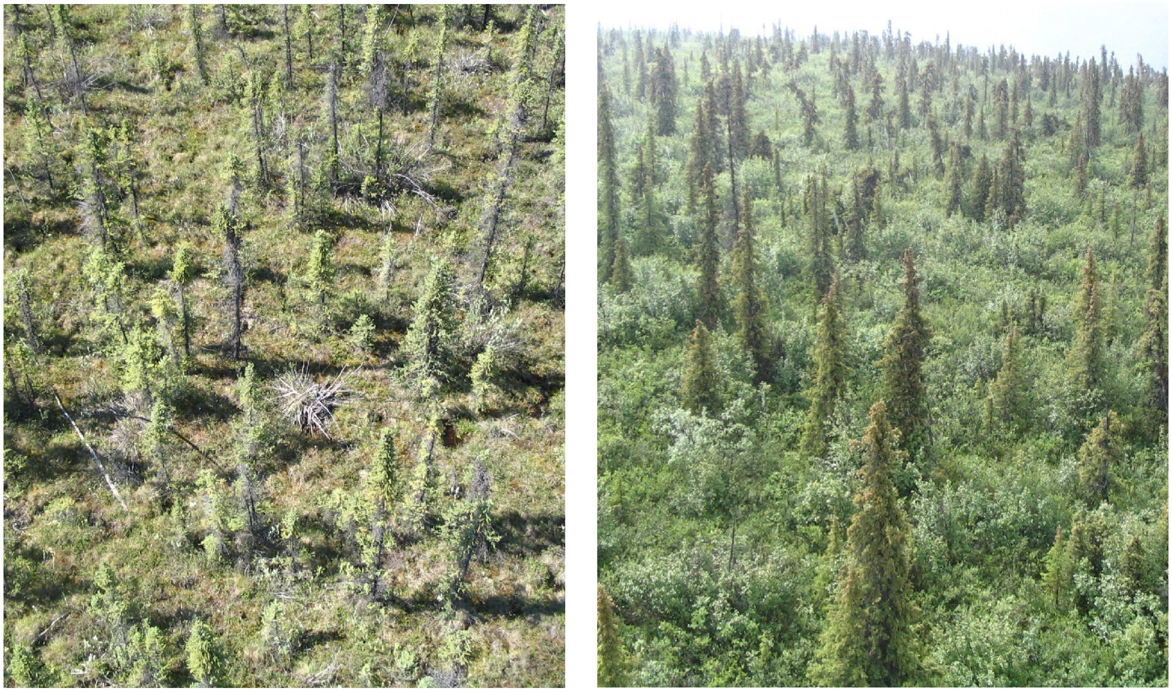


Figure 15. Typical Woodland Needleleaf Other site in lowlands (left) and uplands (right).

Deciduous forest was a primary land cover in the hills and lower slopes of the mountains but was also found in areas of slightly raised elevation or better drainage in the lowland areas as well as in riparian areas. Deciduous species included paper (or white) birch (*Betula papyrifera*), aspen (*Populus tremuloides*), and poplar (*Populus balsamifera*). Poplar was most commonly found along rivers or on the edges of large lakes. Birch and Aspen were found on slopes or raised hummocks, although Aspen tended to dominate only on well-drained, south-facing slopes.

Closed deciduous forest was broken into three subclasses for mapping: Closed Aspen, Closed Deciduous–Willow/Alder, and Closed Deciduous–General which represented all other closed deciduous forest. In many past mapping projects we have been unable to separate deciduous subclasses, but in this image the aspen had a fairly distinctive signature, perhaps due to the specific phenological stage it was in at the time of image acquisition. That distinctive signature, along with the consistent location on south-facing slopes, enabled us to map the aspen with reasonable confidence, although it is likely that some of the smaller and more open patches of aspen, where the signature was less distinct, were missed. The Closed Deciduous-Willow/Alder class, in which the deciduous component consisted of very tall (≥ 4m) willow and/or alder, was not listed in the original classification scheme, but since it had a somewhat distinctive signature it was mapped as a separate class. This class was combined into the Closed Deciduous – General class in Tables 6 and 7 and is considered part of the Closed Decidous – General class in the following discussions.

A general Open deciduous class was mapped but its accuracy was low as there was significant confusion with tall shrub and Closed Deciduous. A very limited amount of Open Aspen was mapped, but undoubtedly there was more of it in the project area, likely mapped as part of the Closed Aspen class or as one of the shrub classes.

Closed Mixed Needleleaf / Deciduous forest was common at the interface between needleleaf and deciduous stands. As might be expected, this class was sometimes confused with both Closed Needleleaf and Closed Deciduous, depending on the mix of tree species present.

Similarly, the Open Mixed Needleleaf/Deciduous class was often confused with other needleleaf and deciduous classes, as well as woodland. In fact, eight of the eleven Open Mixed Needleleaf/Deciduous sites were within +/- 5% of another class or more than one other class, resulting in significant spectral confusion between this class and others. Thus it is likely that the Open Mixed Needleleaf/Deciduous class has a relatively low accuracy in the final map.

Open Mixed Needleleaf/Deciduous, although of limited extent in the project area, was observed in several different growth forms. The first included stands of mature, openly-spaced spruce and deciduous trees with a component of tall shrub in the understory, but the deciduous cover was greater than the tall shrub cover. This form was observed occasionally in riparian areas and at the lowest elevations of the mountain slopes and could be confused with open needleleaf or deciduous classes, depending on the mix of tree species. A second form was found on the slopes of the mountains in the transition zone between areas of denser forest at the lower elevations and shrub communities at higher elevations. In this form, a tall shrub understory made up a greater percentage of the cover than the deciduous trees <u>or</u> the deciduous trees consisted of very tall ($\geq$ 4 meter) forms of shrub species, giving it a spectral signature closer to tall shrub. A third, very different, form of Open Mixed Needleleaf/Deciduous was located in the regenerating burn areas. Here the Open Mixed Needleleaf/Deciduous cover was made up of scattered sapling-sized spruce and deciduous trees, often with scattered tall shrubs and a component of bare ground.

6.1.2 Shrub Cover Types

Shrub cover types were common throughout the project area in poorly drained lowlands, alpine areas, and regenerating burns. Tall shrub was found in riparian floodplains and drainages, on steep alpine slopes, and in regenerating burns, with willow and alder being the most common tall shrub species. Very tall shrubs ($\geq$4 meters) were considered trees and areas in which they dominated were mapped as part of the open and closed deciduous classes. Four subclasses of tall shrub were defined in the classification scheme and all were observed within the project area. These included Tall Shrub – Alder, Tall Shrub – Willow, Tall Shrub – Willow/Alder, and Tall Shrub – Other in which neither alder, willow, or a combination of the two made up more than 75% of all shrubs. In the lowlands, most of the tall shrub consisted of willows with a graminoid understory in riparian floodplains and drainages, although alder was occasionally dominant in these areas. On the alpine slopes and in regenerating burns, both alder and alder/willow mixes were common. Because of the spectral similarity of alder and willow and the fact that the tall shrub sites were often a mix of the two, it was not possible to accurately map the various tall shrub subclasses. Instead, all of the four subclasses were combined and mapped as a general tall shrub class.

Low shrub cover types were found throughout the project area in areas of poor drainage in the lowlands, on the plateaus of hills and mountains, on the upper slopes of mountains, and in regenerating burns. Three low shrub cover types were mapped (Figure 16): Low Shrub Other, Low Shrub Willow, and Low Shrub Tussock Tundra. Dwarf birch and willow were the most common low shrubs, followed by labrador tea and blueberry. Tussock-forming sedge was often present in the lowland low shrub areas and when it exceeded 30% of the cover in a low shrub site, the site was defined as Low Shrub Tussock Tundra. Low Shrub Willow was present in riparian areas, generally with an understory dominated by sedges. The largest concentration of this cover type was in the broad floodplains of the Tanana and Chisana rivers where they parallel the Alaska Highway. Because of the somewhat distinctive signature caused by the presence of the sedge understory, the Low Shrub Willow class was mapped in these areas. Low Shrub Willow was also located in drainages between slopes in the uplands but had a signature closer to that of tall shrub and was rarely successfully mapped. Because only a single Low Shrub Lichen site was visited in the field, this class was mapped as part of the Low Shrub Other class.

Dwarf shrub was found in the alpine zone of the Wrangell Mountains and the more isolated tall mountains of the Yukon-Tanana Uplands ecoregion. Both Dwarf Shrub Lichen and Dwarf Shrub Other classes were mapped, although Dwarf Shrub Lichen was very limited in extent and is based on only two field sites. Dwarf shrub was usually located on the upper slopes of mountains above low shrub and below the rock/gravel.

Figure 16. Examples of low shrub cover types: Low Shrub Willow (upper left), Low Shrub Tussock Tundra (upper right), and Low Shrub Other (bottom).

6.1.3 Wetland Cover Types

Wetland cover types within the project area consisted of wet graminoid (Figure 17), emergent vegetation, and aquatic beds. These cover types were found in and around lakes and in fens throughout the project area. The greatest concentrations of wetlands were observed between the Nabesna and Chisana rivers, southeast of Northway.

Figure 17. Wet Graminoid sites.

Emergent vegetation was one of the sparser cover types within the project area. The most common emergent species were horsetail and buckbean. Buckbean was generally observed in richer fens along with horsetail, moss, sedges, and scattered shrubs. Thus these emergent sites were sometimes confused with moss and wet graminoid. Horsetail was found in pockets or linear strips along the shallow edges of larger lakes. Because of the small size of the horsetail patches and the influence of water through the open "canopy" of the horsetail, it is likely that this type of emergent wetlands was underclassified in the final map. Sparser horsetail was easily confused with water.

It should be noted that the signature of all of these wetland cover types is made up of a combination of vegetation and water. A similar situation is found along the edges of waterbodies where the interface of water and shoreline vegetation results in mixed pixels. For example, the signature of a pixel representing wet graminoid and water may vary little from the signature of a pixel that represents water and tall shrub, depending on the percentage of water and vegetation in each site. Thus, in attempting to map the Wet Graminoid, Aquatic Beds, and Emergent Vegetation cover types, it is inevitable that mixed pixels or mixed image objects around the edges of waterbodies will be inadvertently included and may artificially inflate the acreages of these cover types. Conversely, these cover types may be under-represented in the locations where they actually occur due to confusion with water and other cover types. The user should keep these facts in mind when using the final map.

6.2 Accuracy Assessment

The accuracy of the satellite-derived earth cover classification map is shown in the error matrix located in Appendix D. The error matrix shows percent accuracy as calculated using traditional methods (+/- 0% variation) and fuzzy logic methods (+/- 5% variation).

The error matrix shows the overall percent success in classifying known ground reference sites. In addition to the overall map accuracy, the error matrix shows the producer's and user's accuracy for each class of earth cover shown on the map; essentially each category in the map legend has its own accuracy metric. For all mapped classes, ground truth sites that fall on the major diagonal are classified correctly, and off diagonal entries indicate sites that were classified incorrectly on the image derived earth cover map.

The fuzzy accuracy assessment matrix allows for some additional information to be obtained. Recall that under fuzzy accuracy assessment, some classification errors are acceptable, specifically those where the ground (in this case, helicopter) observation was very close to, but not the same as the image derived earth cover type. These cases, which are simply errors in the traditional matrix, are identified and counted as acceptable matches in the fuzzy matrix. These cases are also informative in that they show both the overall number and types of field observation sites that contain vegetation compositions on the boundary between mapping classes.

A detailed analysis of the accuracy assessment is presented here; refer to Appendix D to examine the error matrix that underpins this analysis.

There were 34 different types of earth cover mapped in Tetlin NWR/Scottie Creek earth cover map. Of these, 8 individual earth cover classes and 1 rolled-up or generalized earth cover class (Closed Deciduous) had sufficient numbers of field sites to perform accuracy assessment. The overall accuracy of the earth cover map was determined to be 72% using conventional accuracy assessment and increased to 79% under fuzzy accuracy assessment which allowed +/- 5% variation in observer canopy closure estimation.

All of the mapped needleleaf classes except Open Needleleaf Lichen had enough sites to set aside some for accuracy assessment. Closed Needleleaf and Open Needleleaf Other both had respectable accuracies, ranging from 79% to 100%. The Woodland Needleleaf Other class, however, had lower accuracies. The producer's accuracy for this class was 60% but increased to a respectable 80% with application of fuzzy logic which allowed for a +/- 5% variation in reference site interpretation. The user's accuracy however was a low 40% and only increased to 53% with fuzzy logic. The low user's accuracy indicates that the

Woodland Needleleaf Other class is likely over-represented in the map. Most of the error involved the incorrect mapping of open needleleaf other and low shrub other sites as woodland needleleaf other.

Woodland forest is often challenging to map because the sparse tree canopy results in a large part of the spectral signature coming from the understory components rather than the trees. Thus it was most often confused with Open Needleleaf Other and Low Shrub Other, depending on the percentage of trees and the composition of the understory. In the uplands, where the understory was sometimes dense tall shrub, Woodland Needleleaf Other was also confused with open and closed mixed needleleaf/deciduous.

Closed Deciduous had good accuracies, ranging from 78.6% producer’s accuracy to 100% user’s accuracy. There was no change in these accuracies with the application of fuzzy logic. Closed Aspen was lumped with Closed Deciduous – General for the accuracy assessment. Even though Closed Aspen was mapped as a separate class, it did not have enough sites to do an accuracy assessment on it alone. Accuracy assessment was not performed on the Open Deciduous map class either, due to a limited number of sites. However, a review of the accuracy with which the training sites were mapped indicated that this class had a low accuracy. Most of the error was with closely related classes: closed deciduous, open mixed needleleaf/deciduous, and tall shrub.

The Tall Shrub – General class had a producer’s accuracy of 75% (no increase with fuzzy logic) and a user’s accuracy of 75% which increased to 87.5% with the application of fuzzy logic. Thus the Tall Shrub-General class appeared to be fairly well mapped. However, a comparison of the training sites against the map indicates error that was not revealed by the accuracy assessment sites. An accuracy assessment matrix generated from the training sites shows that while most (82.4%) of the tall shrub training sites were correctly mapped, a number of sites from other classes were incorrectly mapped as part of the Tall Shrub – General class. In other words, the tall shrub class is over-represented in the map. Most of these errors of commission involved Open Mixed Needleleaf/Deciduous, Open Deciduous, and Closed Deciduous and occurred in riparian areas and at the lower elevations of mountains where there were very tall willow and/or alder shrubs that were treated as deciduous trees or there was a mix of open deciduous trees with an understory of tall shrubs. Over-mapping of the tall shrub class also occurred in the young regenerating burns where young deciduous trees were difficult to distinguish from tall shrubs. There was also some confusion between Tall Shrub – General and both Low Shrub Willow and Low Shrub Other.

Low Shrub Other had a producer’s accuracy of 68.4%, increasing to 74% with fuzzy logic, and a user’s accuracy of 62% (both with and without fuzzy logic). Most of the error involved confusion with Woodland Needleleaf Other and other shrub classes. The lower user’s accuracy indicates that the Low Shrub Other class is somewhat over-represented in the final map. Neither the Low Shrub Willow or Low Shrub Tussock Tundra classes had enough sites to set aside sites for a formal accuracy assessment. However, a comparison of the training sites with the final map suggests that Low Shrub Tussock Tundra is fairly accurately represented in the map, but that Low Shrub Willow is somewhat under-represented in the map, with some of the low shrub willow being incorrectly mapped as tall shrub or low shrub other.

Dwarf Shrub Other had a user's accuracy of 100% and a producer's accuracy of 57.1% that increased to 71.4% with application of fuzzy logic. All of the error involved incorrectly mapping some low shrub other and low shrub tussock tundra sites as dwarf shrub.

Of the wetland classes, wet graminoid and emergent vegetation had enough sites to perform accuracy assessment. The accuracies for these two classes were all relatively high except for the producer's accuracy of 50% for wet graminoid. Two out of the three incorrectly classified wet graminoid sites were classified as emergent vegetation. One of the sites looked as if it had undergone a significant change between the date of the imagery and the date of the field work when the site was visited. The site appeared very wet on the 1999 imagery was but was dry with a lot of dead sedge when visited in the field in 2005. Given this difference, the site probably should have been omitted from the accuracy assessment.

It should be noted that few field sites were captured that represented clear water, turbid water, or the barren areas. Consequently, no accuracy assessment was performed for these classes. However, these classes are among the most straightforward to map from satellite imagery and it was therefore decided to focus the valuable and limited field time on capturing data to assist in the discrimination and mapping of the more spectrally and ecologically complex vegetation communities in the project area. Due to the spectral distinctiveness of the water and barren classes, it is almost certain that the accuracy for these classes would be high, thus only acting to improve the overall accuracy of the final earth cover map.

As stated earlier, some earth cover classes were limited in size and distribution within the project area so that a statistically valid accuracy assessment sample could not be obtained within funding constraints. The lack of accuracy assessment for these classes does not imply that these classes are necessarily inaccurate on the map, but rather that no statistically valid conclusions can be made about the accuracy of these classes.

6.3 Post-1999 Burn Classification

A number of fires occurred within the project area after August 4, 1999, the source date of the base land cover map. In particular, several large fires occurred in 2003 and 2004. To bring the 1999 land cover map up to date, an August 28, 2005 image was acquired and used to map the post-1999 burns within the project area. Six post-1999 burns were identified and mapped using the August 28, 2005 image (Figure 18). Approximately 135,904 hectares (335,826 acres) were burned by these six fires, including 16,128 hectares (39,855 acres) within the refuge during the Black Hills fire in 2003.

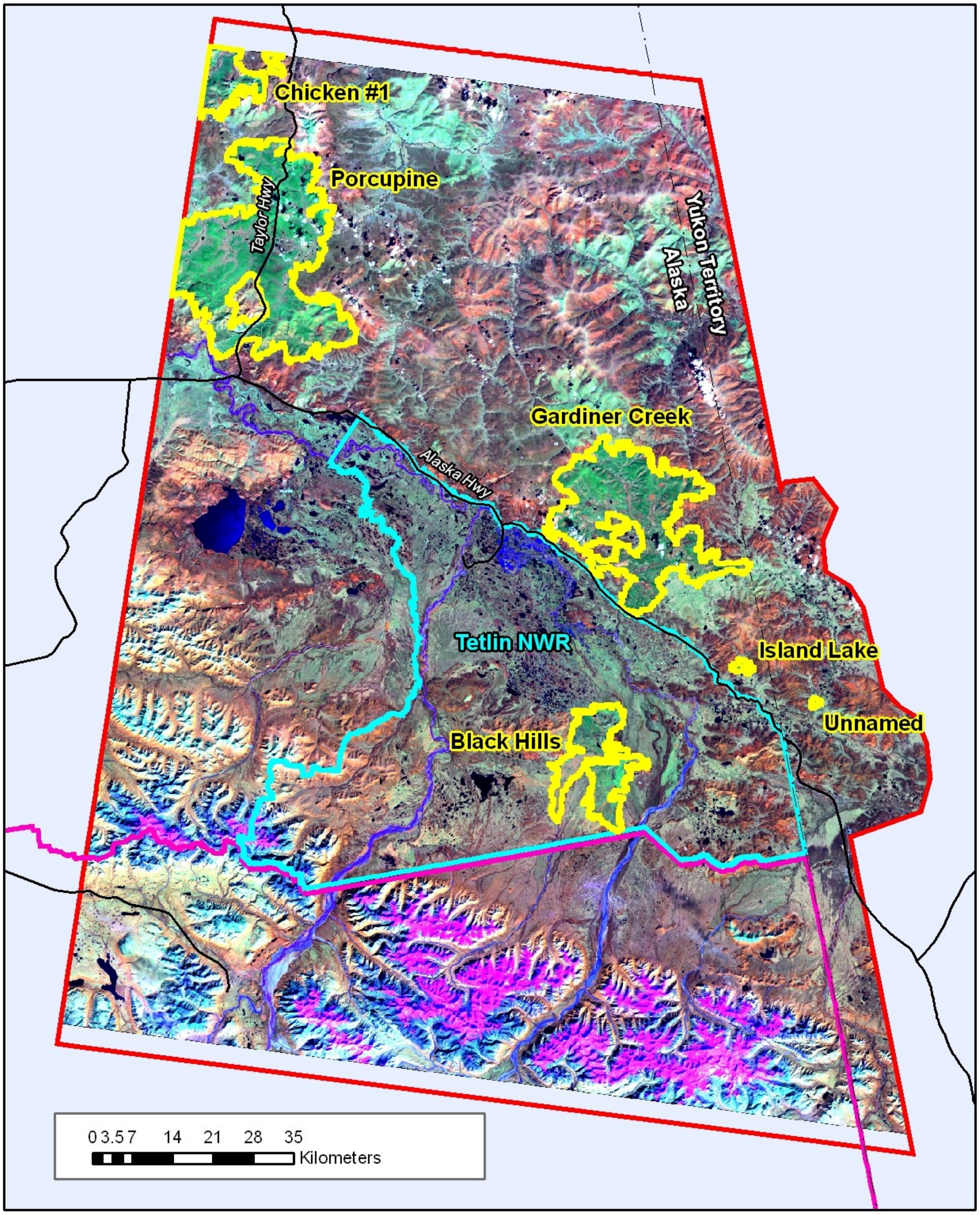


Figure 18. Post-1999 fires mapped with August 28, 2005 TM image.

The areas within the fire perimeters were classified into 8 general classes:

1. Burn – This class represents areas that show little or no indication of vegetation on the image based on the spectral signature. When displaying bands 4,5,3 of the image, the burns have a medium to dark green color. The Normalized Burn Ratio index was used to define this class and separate it from unburned and regenerating vegetation.

2. Unburned / Regenerating – This class includes all the unburned features and lightly burned vegetation that had regenerated after the burn to the point it could be detected on the 2005 imagery. Most of the unburned or lightly burned/regenerating vegetation was located in the valley bottoms and drainages where wetter conditions existed.

Ideally, the unburned and regenerating vegetation would have been mapped as separate classes. However, given the wide variation in spectral signatures resulting from different degrees of fire severity and the similarities in signatures between regenerating and unburned vegetation, it was not possible to reliably separate the unburned and regenerating vegetation throughout the burns. The effects of the early stages of senescence in the August 2005 image added to the spectral confusion between the unburned and regenerating vegetation.

There were, however, two cases of regenerating vegetation that were mapped separately: 1) lightly burned deciduous and tall shrub that recovered the summer following the burn, and 2) the regenerating tussock grass in the Black Hills burn. These two subclasses of regenerating vegetation are described below.

3. Regenerating Deciduous and Tall Shrub – Areas of lightly burned, regenerating deciduous (much of it aspen) and tall shrub had a fairly unique signature in the 2005 image indicating lush new growth and thus were mapped as a separate class. Characteristic of aspen, these were predominantly located on the south-facing slopes. Some of the regenerating deciduous was mapped in areas that were previously classified as needleleaf in the 1999 earth cover map (Figure 19). Presumably there was a presence of aspen in these areas, although subdominant to the needleleaf trees. The spruce trees were killed by the fire, leaving a more open canopy that provided favorable conditions for the lightly burned aspen to regenerate.

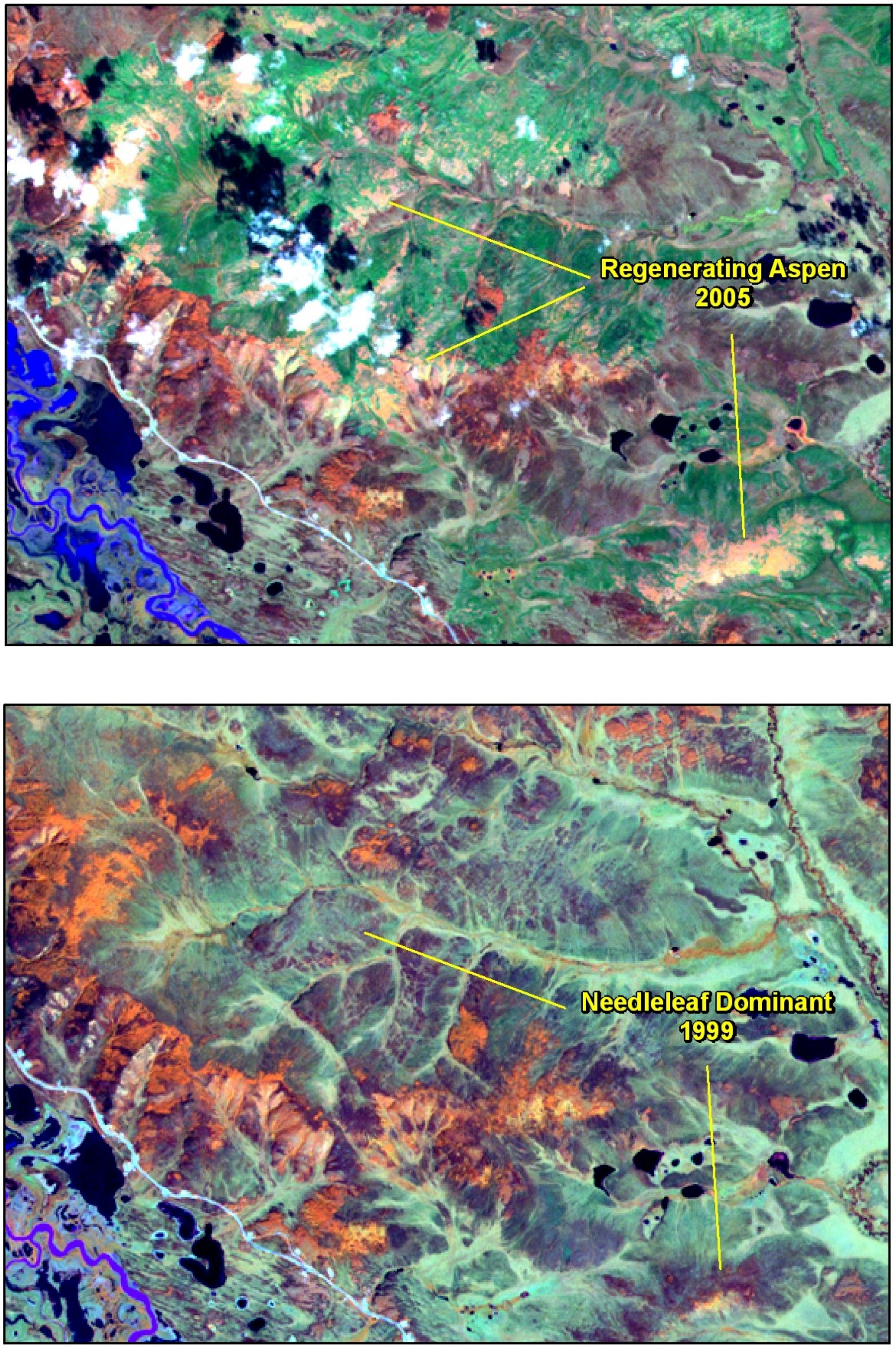


Figure 19. Some of the regenerating aspen in 2005 image was present in areas previously dominated by needleleaf trees .

4. Regenerating Tussock Grass in the Black Hills Burn – Much of the lowlands of the Black Hills burn area had an understory of tussock grass prior to the burn. The tussock grass was present not just in the Low Shrub/Tussock Tundra land cover, but also beneath much of the open spruce of the area. Tussock grass typically regenerates quickly and vigorously after a burn due to the increase in nutrients. This lush regeneration is evidenced in the 2005 image (bands 4,5,3) as areas of muted orange. Because of the strong spatial correlation between tussock grass in the 1999 image and the lush regeneration in the lowlands of the Black Hills burn (Figure 20), it was possible to confidently label the muted orange areas of regeneration as tussock grass. In the other burns, the areas of known tussock grass did not have the same consistent signature observed in the Black Hills burn and therefore were not mapped separately. Perhaps this is due to the fact that the Black Hills burn was two years old when the 2005 image was acquired while the other burns were younger, having burned in 2004 or 2005.

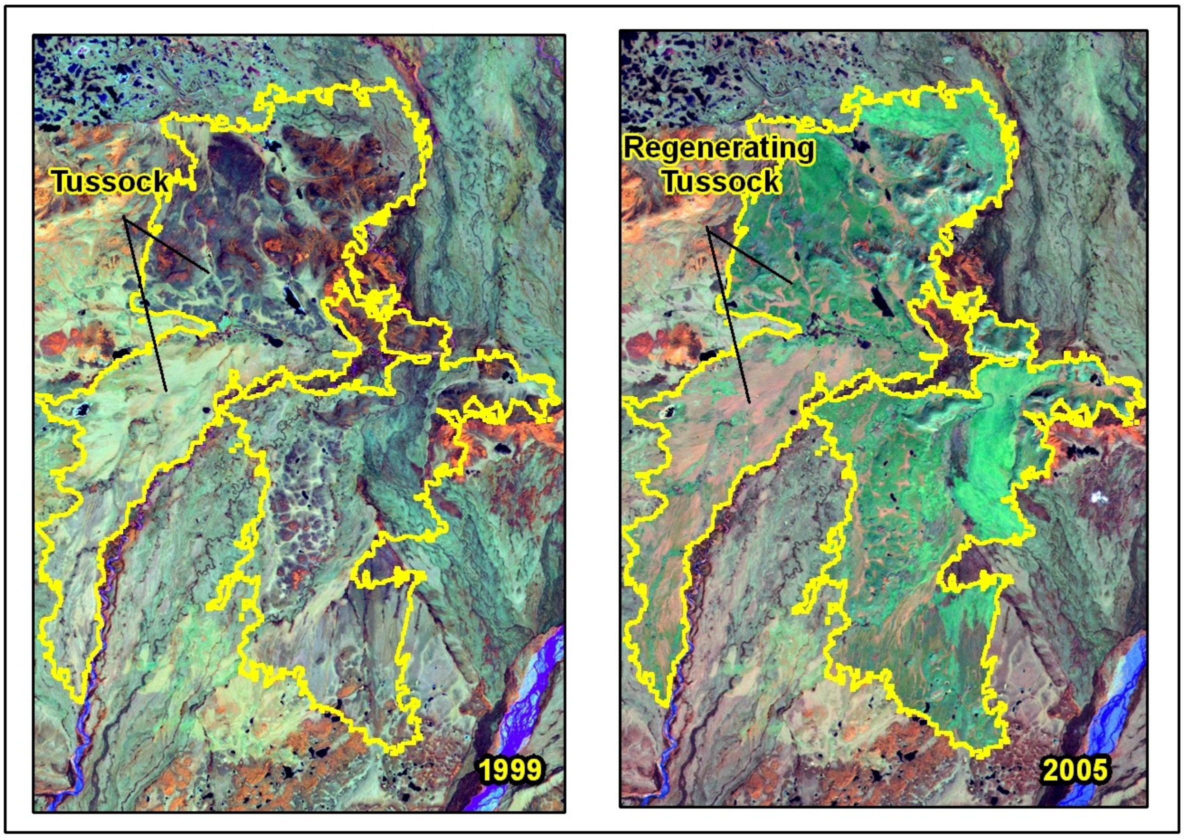


Figure 20. Tussock is light green in the 1999 image; regenerating tussock is light orange in 20005 image.

The remaining classes (with the exception of the Roads class), listed below, were included because these cover types occurred within the burn perimeter, but obscured the earth's surface on the image, making the determination of whether the land cover was burned or not impossible.

5. Clouds – Clouds that were present within the burn perimeter on the 2005 image.

6. Cloud Shadows – Cloud shadows that were present within the burn perimeter on the 2005 image.

7. Roads – The Taylor Highway bisected the Porcupine burn.

8. Terrain Shadows – Terrain shadows that were present within the burn perimeter on the 2005 image.

In Figure 20, the post-1999 burns have been overlaid over the 1999 earth cover map.

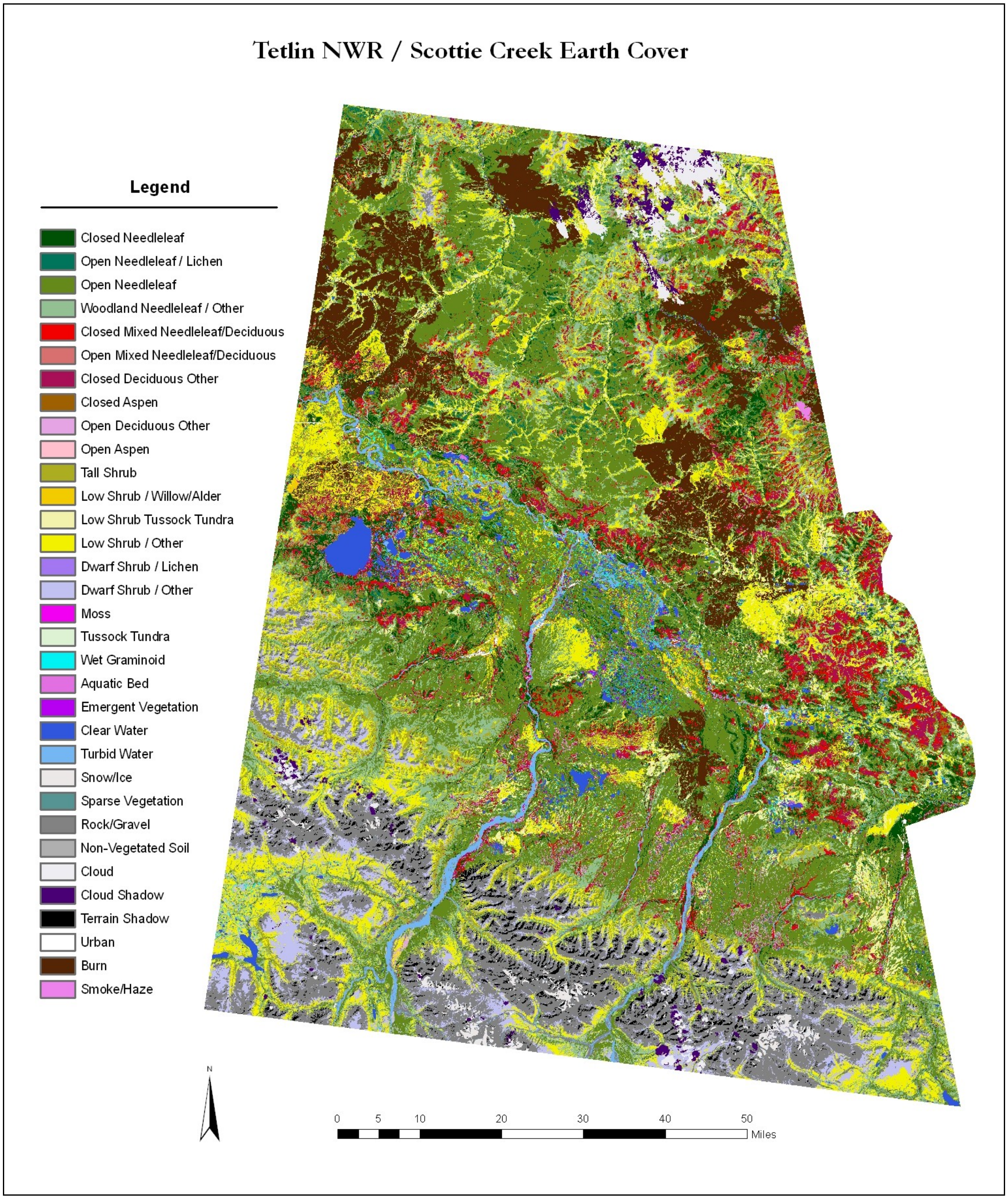


Figure 21. Tetlin NWR / Scottie Creek 1999 earth cover with 2000-2005 burns added.

6.4 Final Products

The final deliverables from this project include:

- Tetlin NWR / Scottie Creek Earth Cover Map – digital format (ERDAS Imagine .img and ArcGrid format)
- 2000-2005 Burn Map – digital format (ERDAS Imagine .img and ArcGrid format)
- TM imagery used for the project – digital format (ERDAS Imagine .img format)
- Field site database - .dbf files
- Field photos - .jpgs
- Duff Extension for ArcView for viewing the field data and field photos
- Hardcopy maps (and .pdf plot files) of the classified map and TM imagery
- Digital / Hardcopy User's Guide

The ArcView extension (duff_dec3-03.avx) was developed by the U.S. Bureau of Land Management for viewing the field photos and field data in ArcView. Instructions are included in Appendix E on how to install and use the Duff Extension. This extension also has a query function (although it has some bugs) allowing the user to query the field database for sites meeting user-defined criteria. Appendix F provides a detailed explanation of the field database structure and a description of the fields in the database.

7.0 Summary

A satellite imagery-based earth cover mapping project was completed for a 2.2 million hectare (5.4 million acres) area centered on Tetlin National Wildlife Refuge in the southeastern corner of interior Alaska. The project area included the Scottie Creek area in Yukon Territory, Canada, and the northern portion of Wrangell-St. Elias National Park. The imagery for the project was acquired during the summer of 1999. Field data was collected via helicopter at 397 sites from June 19-29, 2005. Image segmentation, membership functions and supervised classification techniques were applied to map 34 earth cover classes. The overall accuracy of the image classification was 72% with a strict interpretation of the reference data and 79% with a +/- 5% variation in reference data. Most of the error involved misclassification between related cover types, such as between forested classes or between shrub classes. The resulting earth cover map indicates that the three most extensive earth cover classes within the project area were Open Spruce Other (32.6%), Woodland Needleleaf Other (11.8%), and Low Shrub Other (11.5%). Wetland cover types (including water) made up 4% of the overall project area and 10% of Tetlin National Wildlife Refuge. The products from this project include a digital earth cover map, digital and hardcopy map products, a complete digital field database including field photographs, and this user's guide. This data will aid in the critical process of resource planning for this valuable and diverse area.

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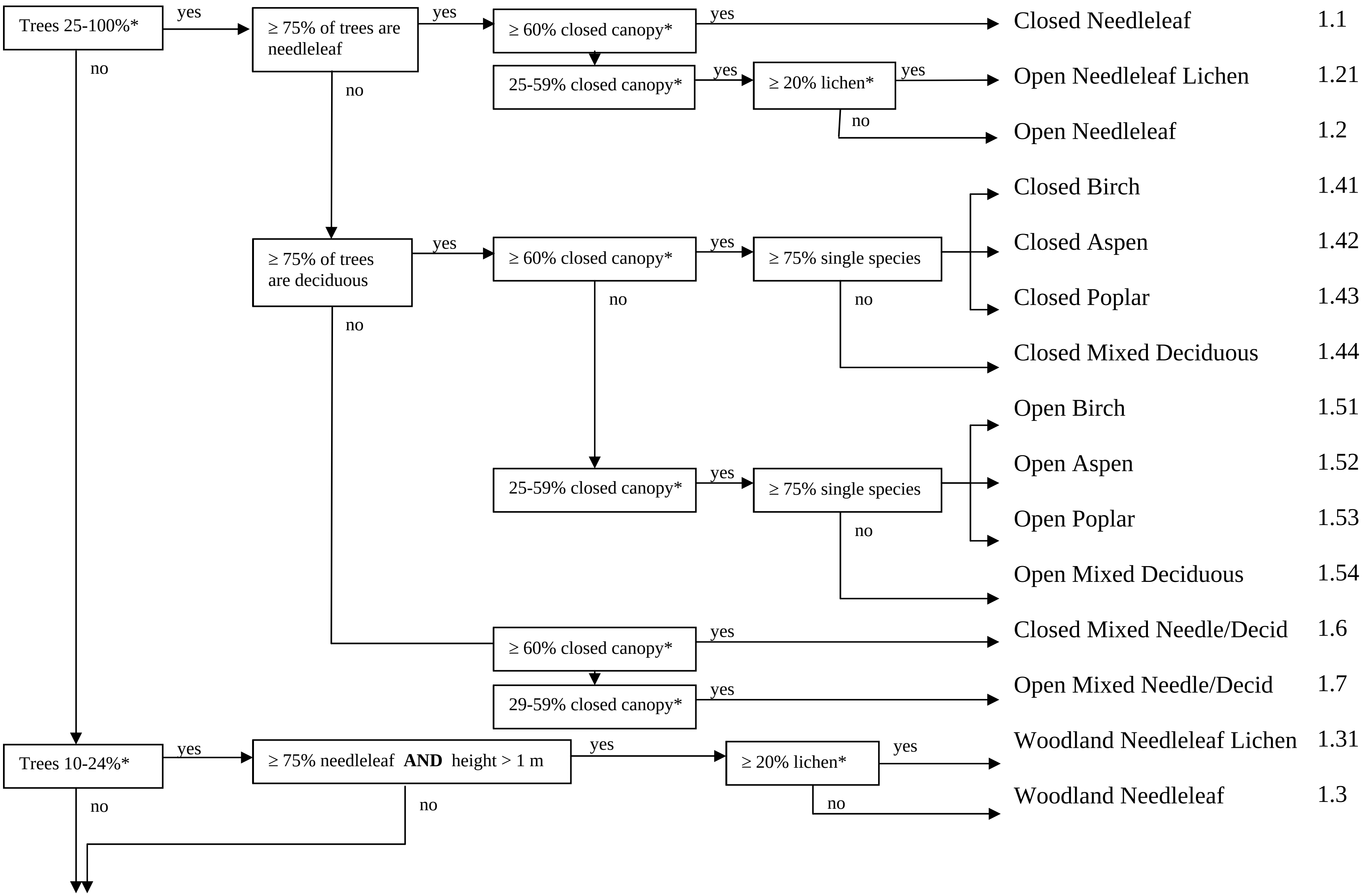
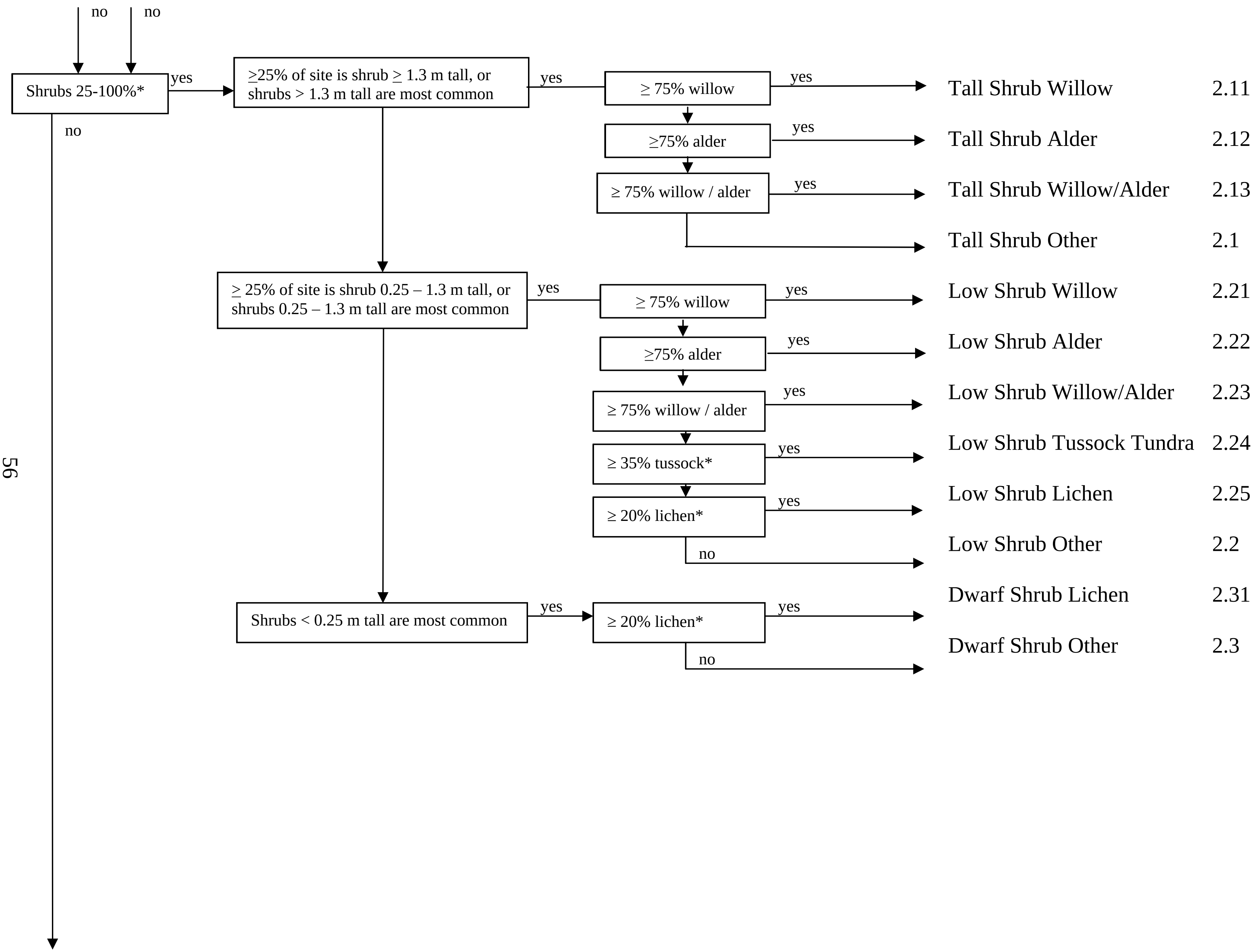
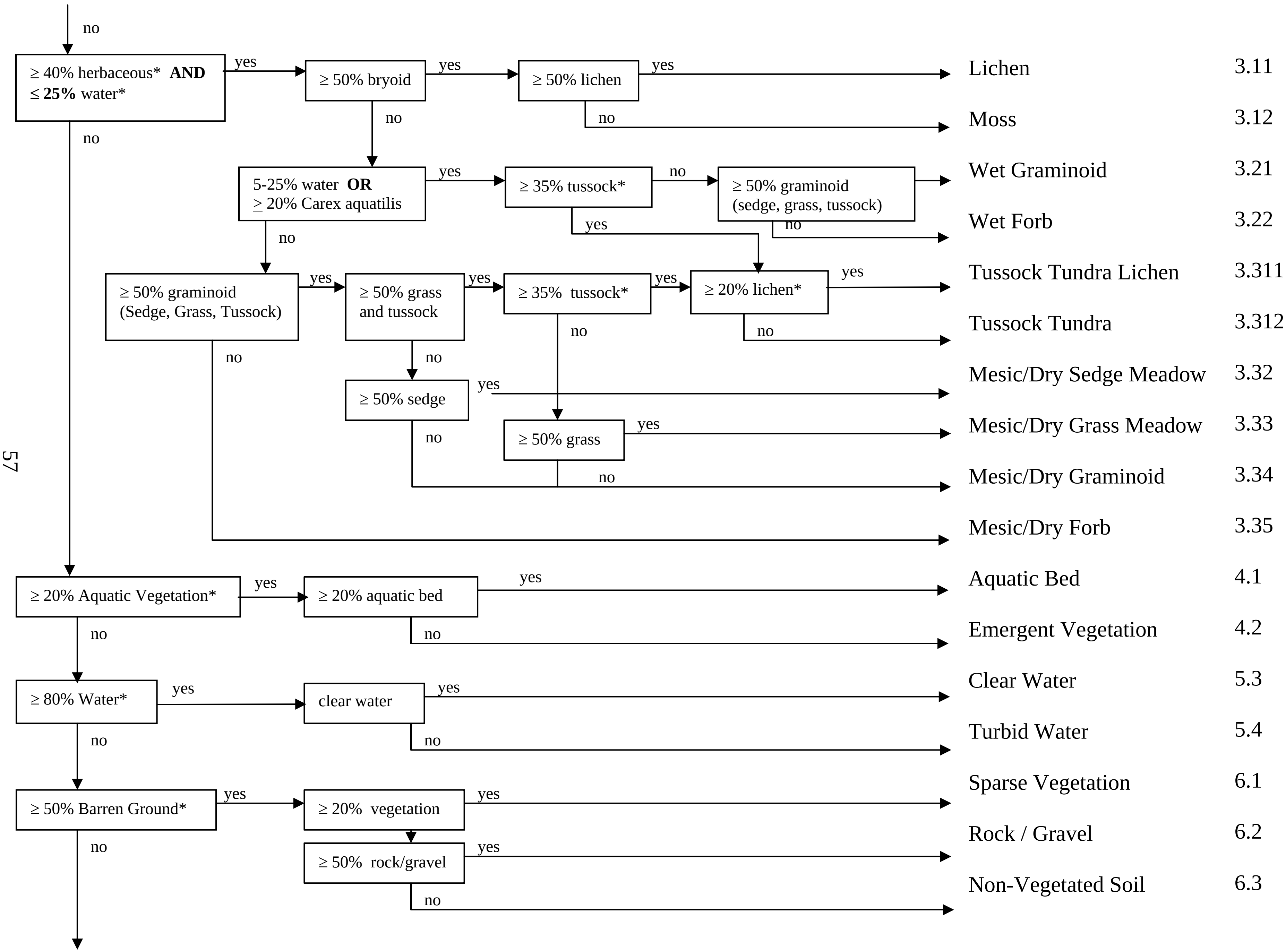
Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA.

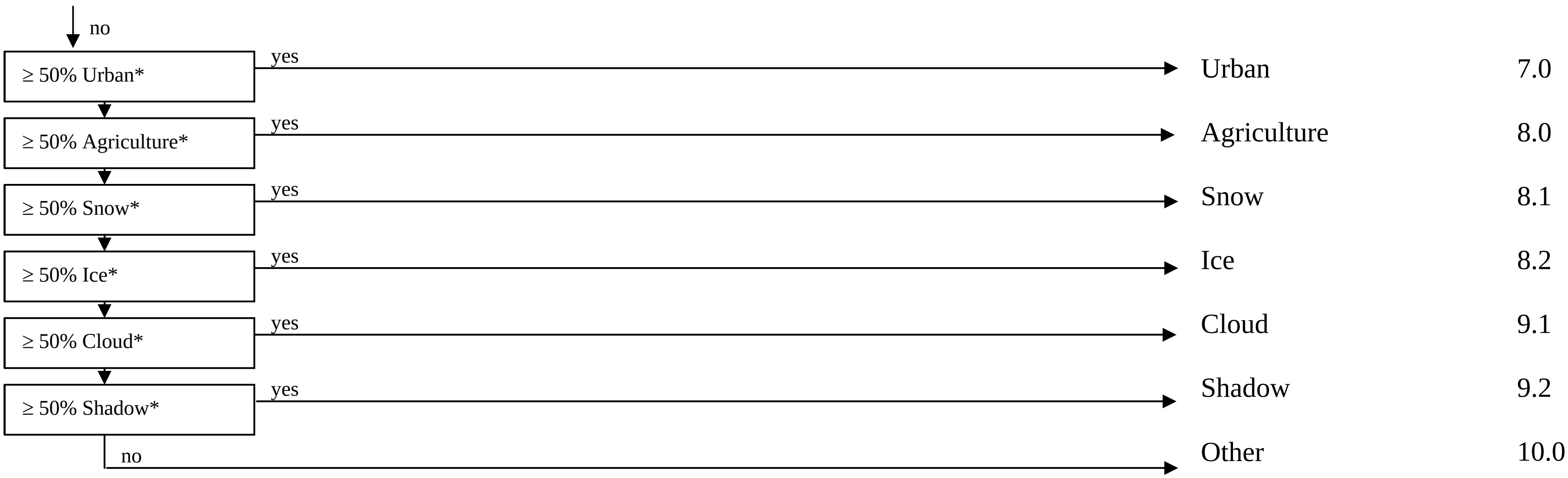
Appendix A. Tetlin NWR / Scottie Creek Classification Decision Tree

(* Indicates %of Total Land Cover, otherwise % of Major Category)




no
no
Shrubs 25-100%*
yes
no
≥25% of site is shrub ≥ 1.3 m tall, or shrubs > 1.3 m tall are most common
yes
≥ 75% willow
yes
Tall Shrub Willow 2.11
≥75% alder
yes
Tall Shrub Alder 2.12
≥ 75% willow / alder
yes
Tall Shrub Willow/Alder 2.13
Tall Shrub Other 2.1
≥ 25% of site is shrub 0.25 – 1.3 m tall, or shrubs 0.25 – 1.3 m tall are most common
yes
≥ 75% willow
yes
Low Shrub Willow 2.21
≥75% alder
yes
Low Shrub Alder 2.22
≥ 75% willow / alder
yes
Low Shrub Willow/Alder 2.23
≥ 35% tussock*
yes
Low Shrub Tussock Tundra 2.24
≥ 20% lichen*
yes
Low Shrub Lichen 2.25
no
Low Shrub Other 2.2
Shrubs < 0.25 m tall are most common
yes
≥ 20% lichen*
yes
Dwarf Shrub Lichen 2.31
no
Dwarf Shrub Other 2.3


no
≥ 40% herbaceous* AND ≤ 25% water*
yes
≥ 50% bryoid
yes
≥ 50% lichen
yes
Lichen 3.11
no
Moss 3.12
no
no
5-25% water OR ≥ 20% Carex aquatilis
yes
≥ 35% tussock*
no
≥ 50% graminoid (sedge, grass, tussock)
Wet Graminoid 3.21
no
Wet Forb 3.22
yes
no
≥ 50% graminoid (Sedge, Grass, Tussock)
yes
≥ 50% grass and tussock
yes
≥ 35% tussock*
yes
≥ 20% lichen*
yes
Tussock Tundra Lichen 3.311
no
Tussock Tundra 3.312
no
no
no
≥ 50% sedge
yes
Mesic/Dry Sedge Meadow 3.32
≥ 50% grass
yes
Mesic/Dry Grass Meadow 3.33
no
no
Mesic/Dry Graminoid 3.34
Mesic/Dry Forb 3.35
≥ 20% Aquatic Vegetation*
yes
≥ 20% aquatic bed
yes
Aquatic Bed 4.1
no
Emergent Vegetation 4.2
no
≥ 80% Water*
yes
clear water
yes
Clear Water 5.3
no
Turbid Water 5.4
no
≥ 50% Barren Ground*
yes
≥ 20% vegetation
yes
Sparse Vegetation 6.1
≥ 50% rock/gravel
yes
Rock / Gravel 6.2
no
Non-Vegetated Soil 6.3
no


no
≥ 50% Urban*
yes
Urban
7.0
≥ 50% Agriculture*
yes
Agriculture
8.0
≥ 50% Snow*
yes
Snow
8.1
≥ 50% Ice*
yes
Ice
8.2
≥ 50% Cloud*
yes
Cloud
9.1
≥ 50% Shadow*
yes
Shadow
9.2
no
Other
10.0

Appendix B. Earth Cover Types Represented By Field Sites

(Blue text = Mapped classes. **Blue/Bold text** = Classes for which accucracy assessment was performed.)

Land Cover Class	Subclasses	Total	Training	Accuracy
Closed Needleleaf		16	11	5
Open Needleleaf / Lichen		13	13	0
Open Needleleaf / Other		56	37	19
Closed Deciduous / Other				
	Closed Aspen	8	6	2
	Closed Birch	18	12	6
	Closed Poplar	4	3	1
	Closed Mixed Deciduous	9	6	3
	*Closed Deciduous - Willow/Alder	6	4	2
Open Deciduous				
	Open Aspen	1	1	0
	Open Birch	2	2	0
	Open Poplar	3	3	0
	Open Mixed Deciduous	6	6	0
Closed Mixed Needleleaf/Deciduous		13	13	0
Open Mixed Needleleaf/Deciduous		11	11	0
Woodland Needleleaf				
	Woodland Needleleaf / Lichen	3	3	0
	Woodland Needleleaf / Other	30	20	10
Tall Shrub				
	Tall Shrub / Willow	6	4	2
	Tall Shrub / Alder	5	4	1
	Tall Shrub / Willow/Alder	7	5	2
	Tall Shrub / Other	8	5	3
Low Shrub / Willow		10	10	0
Low Shrub / Tussock Tundra		8	8	0
Low Shrub / Other				
	Low Shrub / Lichen	1	1	0
	Low Shrub / Other	56	37	19
Dwarf Shrub / Lichen		2	2	0
Dwarf Shrub / Other		21	14	7
Moss		5	5	0
Wet Graminoid		18	12	6
Mesic/Dry Forb		2	2	0
Tussock Tundra / Other		8	8	0
Aquatic Bed		10	10	0
Emergent Vegetation		18	12	6
Clear Water		1	1	0
Turbid Water				
Sparse Vegetation		1	1	0
Rock/Gravel		3	3	0
Non-vegetated Soil		1	1	0
Urban				
Snow/Ice				
Cloud/Haze				
Cloud Shadow				
Terrain Shadow				
Recent Burn				
Smoke				
Other		7	7	0
Total		**397**	**303**	**94**

* Closed Deciduous - Willow/Alder was added as a subclass to Closed Deciduous during the mapping process. These sites belonged to the Closed Mixed Deciduous class under the original classification scheme.

Appendix C. Earth Cover Class Descriptions

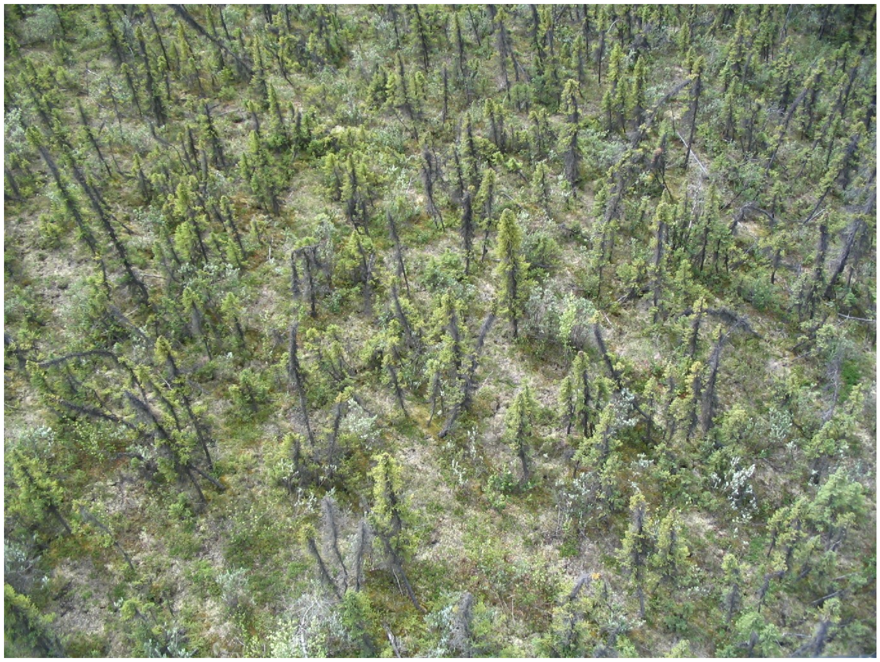
<u>1.0 Forest</u>
Needleleaf and Deciduous Trees-
The needleleaf species observed in the project area were black spruce (*Picea mariana*) and white spruce (*Picea glauca)*. White spruce tended to occur in the uplands and on rich riparian floodplains, while black spruce was common on north-facing slopes of the uplands, in the less well-drained lowlands, and on the lower slopes of the uplands.

Deciduous tree species included white birch (*Betula papyrifera*), balsam poplar (*P. balsamifera*), and aspen (*P. tremuloides*). Deciduous stands were found on river floodplains, on the hills and mountain sides, and on slightly raised hummocks in the lowlands. Mixed deciduous/coniferous stands were present in the same areas as pure deciduous stands and in the interface between deciduous and needleleaf stands.

1.1 Closed Needleleaf
At least 60% of the cover was trees, and $\geq$75% of the trees were needleleaf. Found throughout the project area in the hills (often on the north-facing slopes) and in the floodplains of rivers.

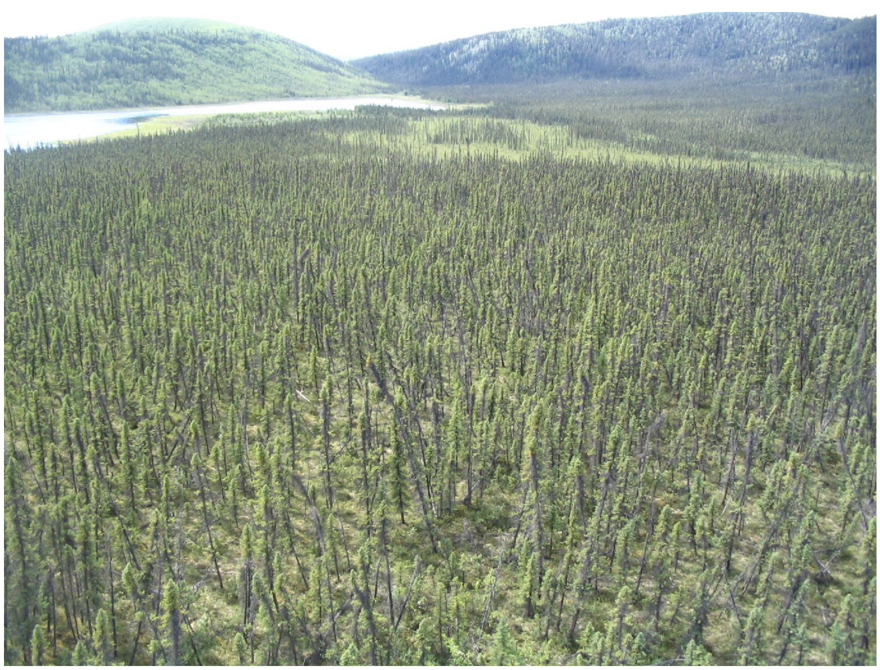
1.2.1 Open Needleleaf / Lichen

25-59% of the cover was trees, ≥75% of the trees were needleleaf, and ≥20% of the understory was lichen. Not widely found in project area and where found did not have heavy concentrations of lichen.



1.2.2 Open Needleleaf / Other

25-59% of the cover was trees, and ≥75% of the trees were needleleaf. Common throughout study area. Primarily found on the poorly drained lowlands and slopes of the hills.



1.3.2 Woodland Needleleaf / Other

10-24% of the cover was trees, and ≥75% of the trees were needleleaf with a height greater than 1 meter. Found in the poorly drained lowlands, often with low shrubs and tussock-forming sedge and at higher elevations with understories of low and tall shrubs.

1.4.4 Closed Deciduous - General

At least 60% of the cover was trees, and ≥75% of the trees were deciduous. Common in the hills, lower elevations of mountains and along river floodplains. This class is a rollup of the Closed Birch, Closed Poplar, and Closed Mixed Deciduous subclasses. Closed Deciduous – Willow/Alder was mapped separately, but is considered part of the Closed Deciduous – General class. Closed Aspen was mapped as a separate class.

1.4.2 Closed Aspen
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥ 75% of the deciduous trees were aspen. Stands dominated by aspen generally occurred on well-drained, south-facing slopes in the areas of low, rolling hills and mountains.

1.5 Open Deciduous - General
25-59% of the cover was trees, and ≥75% of the trees were deciduous. This class was of limited extent, but could be found in riparian areas, often with a tall shrub understory or with a deciduous component made up of very tall willow and/or alder, and in regenerating burns. Occasionally found as mature stands in the uplands, but these were usually within +/- 5% of being Closed Deciduous.

1.5.2 Open Aspen
Trees made up 25-59% of the cover, ≥ 75% of the trees were deciduous, and ≥ 75% of the deciduous trees were aspen. Generally found on south-facing slopes in the areas of low, rolling mountains.

1.6 Closed Mixed Needleleaf/Deciduous

At least 60% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class was distributed throughout image, generally at the interface between deciduous and needleleaf stands.

1.7 Open Mixed Needleleaf/Deciduous

Trees made up 25-59% of the cover, but neither needleleaf nor deciduous trees made up ≥ 75% of the tree cover. Although of limited extent in the project area, this class was observed in three different forms: 1) in riparian areas or lower slopes of the mountains as mature stands of openly-spaced spruce and deciduous trees with a component of tall shrub in the understory; 2) on the slopes of mountains with the deciduous component made up of very tall willow or alder or a deciduous component that was dominated by an larger % of tall shrub in the understory; or 3) in regenerating burns made up of sapling-sized spruce and deciduous trees.

2.0 Shrub

The shrub classes were dominated by willow species (*Salix spp.*), bog birch (*Betula glandulosa*), alder (*Alnus crispa*), and Labrador tea (*Ledum*) species. However, the proportions of shrub species and their relative heights varied widely, which created difficulties in determining whether a site was made up of tall or low shrub. As a result, the height of the shrub species making up the largest proportion of the site dictated whether the site was labeled tall, low or dwarf shrub. The shrub heights were averaged within a genus, as in the case of a site with both tall and low willow shrubs. Tall shrubs generally had a major willow or alder component or a mixture of willow and alder. It was found most often in drainages and at the upper elevations in the mountains. The most common low shrubs were bog birch, willow, Labrador tea, and blueberry.

2.1 Tall Shrub
Shrubs made up 25-100% of the cover, $\geq$25% of the site is shrub $\geq$1.3 meters in height or shrubs $\geq$1.3 meters in height are the most common in the site. This class is a roll-up of Tall Shrub Willow, Tall Shrub Alder, Tall Shrub Willow/Alder, and Tall Shrub Other subclasses. Given the similar signatures of willow and alder and the fact that they were often mixed, it was not possible to spectrally separate the different subclasses for mapping. This class was found most often in riparian areas, drainages between slopes, at upper elevations in the mountains or in regenerating burn areas.

2.2.4 Low Shrub / Tussock Tundra
Shrubs made up 25-100% of the cover, $\geq$25% of the site is shrub 0.25 – 1.3 meters in height or shrubs 0.25-1.3 meters in height are the most common shrubs in the site, and $\geq$35% tussock graminoids. This class was found in extensive patches in the flat, poorly drained valleys of the project area.

2.2.6 Low Shrub / Other

Shrubs made up 25-100% of the cover, $\geq$25% of the site is shrub 0.25 – 1.3 meters in height or shrubs 0.25-1.3 meters in height are the most common shrubs in the site. Found throughout the project area in the valleys and at upper elevations of the mountains. Most common low shrubs were dwarf birch, willow species, and ledum species.

2.2.3 Low Shrub / Willow

Shrubs made up 25-100% of the cover, $\geq$25% of the site is shrub 0.25 – 1.3 meters in height or shrubs 0.25-1.3 meters in height are the most common shrubs in the site, and $\geq$ 75% of the shrubs are willow. This cover type was found in fens and riparian floodplains.

2.31 Dwarf Shrub Lichen

Shrubs made up 40-100% of the cover, shrub height was $\leq$ .25 meters, and $\geq$20% of the cover was made up of lichen. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. It was nearly always found at higher elevations on hilltops, mountain slopes, and plateaus.

2.3 Dwarf Shrub Other

Shrubs made up 40-100% of the cover, the shrub height is $\leq$ .25 meters. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids, and some rock. It was nearly always found at higher elevations on hilltops, mountain slopes, and plateaus.

3.0 Herbaceous

The classes in this category included bryoids, forbs, and graminoids. Bryoids were present as a component in many of the other classes, particularly in the lowlands.

3.1.2 Moss

Composed of ≥40% herbaceous species, ≤25% water, and where ≥50% of the herbaceous cover was moss species. This class was found in small wetland basins in the lowlands, often with a minor component of sedge or horsetail.

3.2.1 Wet Graminoid

Composed of ≥40% herbaceous species, ≥5 and ≤25% water or ≥20% wet sedge, and where ≥50% of the herbaceous cover was graminoid. Found around edges of lakes and in herbaceous fens running through the lowlands of the project area. These sites are seasonally flooded and may be observed in different states of flooding or saturation during the year.

4.0 Aquatic Vegetation

The aquatic vegetation was divided into Aquatic Bed and Emergent classes. The Aquatic Bed class was dominated by plants with leaves that float on the water surface, with the most common species being pond lilies (*Nuphar spp.*). The Emergent Vegetation class was composed of species that were present in standing water, including freshwater forbs such as horsetails (*Equisetum* spp.) and buckbean (*Menyanthes trifoliata).*

4.1 Aquatic Bed

Aquatic vegetation made up $\geq$20% of the cover, and $\geq$20% of the vegetation was composed of plants that grow principally on or near the surface of the water. Plants may be attached to the substrate or float freely in the water. Pond lily (*Nuphar spp*.)was the most common aquatic species.

4.2 Emergent Vegetation
Aquatic vegetation made up ≥20% of the cover, and ≥20% of the vegetation was composed of erect, rooted herbaceous hydrophytes. Most common emergent plants were horsetails (*Equistum spp*.) and buckbean (*Menyanthes trifoliata*).

5.0 Water
Includes both clear and turbid water found in lakes, streams, rivers, and wetlands.

5.1 Snow
$\geq$50% snow cover.

5.2 Ice
$\geq$50% ice cover.

5.3 Clear Water
Composed of $\geq$80% clear water.

5.4 Turbid Water
Composed of $\geq$80% turbid water.

6.0 Barren
This class included sparsely vegetated sites, riparian gravel bars, and rock/gravel faces in the mountains above the treeline.

6.1 Sparse Vegetation
At least 50% of the area was barren, but vegetation made up $\geq$20% of the cover. This class was generally found on riparian gravel bars or on rocky or very steep slopes. The plant species were generally dwarf shrubs.

6.2 Rock/Gravel
At least 50% of the area was barren, $\geq$50% of the cover was composed of rock and/or gravel, and vegetation made up less than 20% of the cover. This class was found on steep slopes at the upper elevations of the mountains and on gravel bars along the rivers.

<u>7.0 Urban</u>
At least 50% of the area was urban.

9.1 Cloud/Haze
At least 50% of the cover was cloud or haze.

9.2 Cloud Shadow

At least 50% of the cover was cloud shadow,

9.3 Terrain Shadow
At least ≥50% of the cover was masked by terrain shadow.

10.1 Recent Burn
Includes areas that have been relatively recently burned such that vegetation is either limited or the vegetation signature is masked by the burn litter, making classification of the area difficult.

10.2 Smoke/Haze
Areas that are obscured in the image by heavy smoke or haze.

Appendix D. Accuracy Assessment Error Matrix

		Reference Class													
	Class	Closed Needleleaf	Open Needleleaf / Other	Woodland Needleleaf / Other	Closed Deciduous	Tall Shrub	Low Shrub / Tussock Tundra	Low Shrub / Other	Dwarf Shrub / Other	Tussock Tundra	Wet Graminoid	Emergent Vegetation	Total	User's (+/- 0%)	User's (+/- 5%)
Mapped Class	Closed Needleleaf	4											4	100.0%	100.0%
	Open Needleleaf	(1,0)	15		1								17	88.2%	94.1%
	Woodland Ndl		(1,3)	6	1			(1,3)					15	40.0%	53.3%
	Closed Deciduous				11								11	100.0%	100.0%
	Tall Shrub			(1,0)		6		1					8	75.0%	87.5%
	Low Shrub/Tussock Tundra			(1,0)					(1,0)				2	0.0%	100.0%
	Low Shrub / Other			2	1	2		13	2		1		21	61.9%	61.9%
	Dwarf Shrub / Other								4				4	100.0%	100.0%
	Tussock Tundra							1					1	0.0%	0.0%
	Wet Graminoid										3		3	100.0%	100.0%
	Emergent Vegetation										2	6	8	75.0%	75.0%
	Total	5	19	10	14	8	0	19	7	0	6	6	94		
	Producer's (+/- 0%)	80.0%	78.9%	60.0%	78.6%	75.0%	-----	68.4%	57.1%	-----	50.0%	100.0%		**72.3%**	
	Producer's (+/- 5%)	100.0%	84.2%	80.0%	78.6%	75.0%	-----	73.7%	71.4%	-----	50.0%	100.0%			

Diagonal cells indicate sites that were accurately mapped at the +/- 0% level of variation.
Off-diagonal cells are represented as follows: (a,b) where a = acceptable match with +/- 5% variation in interpretation and b=incorrectly mapped sites with +/- 5% variation.

Total No. of Sites =	94
Total Correct (Sum of major diagonal) =	68
Total Off-diagonal Acceptable =	6
Overall Accuracy (+/- 0%) =	**72.3%**
Overall Accuracy (+/- 5%) =	**78.7%**

Note: Accuracy assessment was not performed for the Low Shrub / Tussock Tundra and Tussock Tundra classes, but they are included in the error matrix because one or more accuracy assessment sites were incorrectly classified to these classes. These classes were included in the error matrix to show errors of commission.

Appendix E. DUFF Data and Photo Viewer Extension, Version 1

Installation and "How to Run" the Extension

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Installation and Requirements

Requirements:

1. ArcView 3.1 or 3.2 with the Dialog Designer extension. (NOTE: The Dialog Designer extension comes with ArcView 3.1 and 3.2.)
2. It is assumed that the machine on which the extension is to be run has the environmental variable $AVHOME set to the directory where ArcView is located. The environmental variable $AVEXT should also be set to the Ext32 directory where ArcView is located.
3. The structure of the field data is important. The following directories must be at the same directory level:

   .\arccovs
   .\photos

   where the photos are set up under the photos directory as shown in the following example:

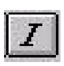
   .\photos\2003-MMAC-1\0703\sess1\0703_001.jpg   (0703 is the month/day)

Installation:

1. Copy the duff.avx file to the ArcView extension directory (Ext32). Generally this directory is located at c:\esri31\AV_gis30\Arcview\Ext32. If the user has set the $USEREXT variable to another location, the extension can be placed there since ArcView will look in that directory for all extensions.
2. Open a new ArcView session, go to File -> Extensions, and turn on the DUFF Data and Photo Viewer extension.

Using the DUFF Data and Photo Extension:

1. As described under Installation, make sure the DUFF Data and Photo Viewer extension is turned on in ArcView.
2. Load the xxxx_fld_sts coverage from the /arccovs directory into a view, where xxxx is the project abbreviation (Ex: GALE for Galena).
3. Load the three .dbf files from /arccovs into the ArcView project. To do this, click on the Tables icon in the Project Menu and then click Add. You will be prompted to enter the .dbf files to be loaded. The three .dbf files are xxxx_site_species.dbf, xxxx_species.dbf, and xxxx_site_photo.dbf.
4. Once the DUFF Data and Photo Viewer extension is turned on, the following buttons/tools will appear on the ArcView menu bars:


the DUFF Info Tool can be used to access the field info from a selected site.


the DUFF Photo tool can be used to view the field photos related to a selected field site.


the DUFF Inquiry button can be used to query the field database according to user specified criteria.

5. Make sure the xxxx_fld_sts coverage is the **<u>active</u>** theme before using the above tools.

<u>Steps to run the Inquiry Button:</u>

NOTE: Due to a bug in the program, you must deselect all sites before using the Inquiry Button. If you have sites selected when you use the Inquiry Button, no sites will be returned in response to your inquiry. We hope to correct this error in the near future. –Ducks Unlimited, Inc.

1. Select a way of identifying up to 3 species: 4 letter code (Symbol), Common Name, or Scientific Name.
2. Select the type of physical parameter(s) to examine for a single species: either percent cover or height or both.
3. Select a mathematical operator for the physical parameter to examine. Note this is specific to each species selected.

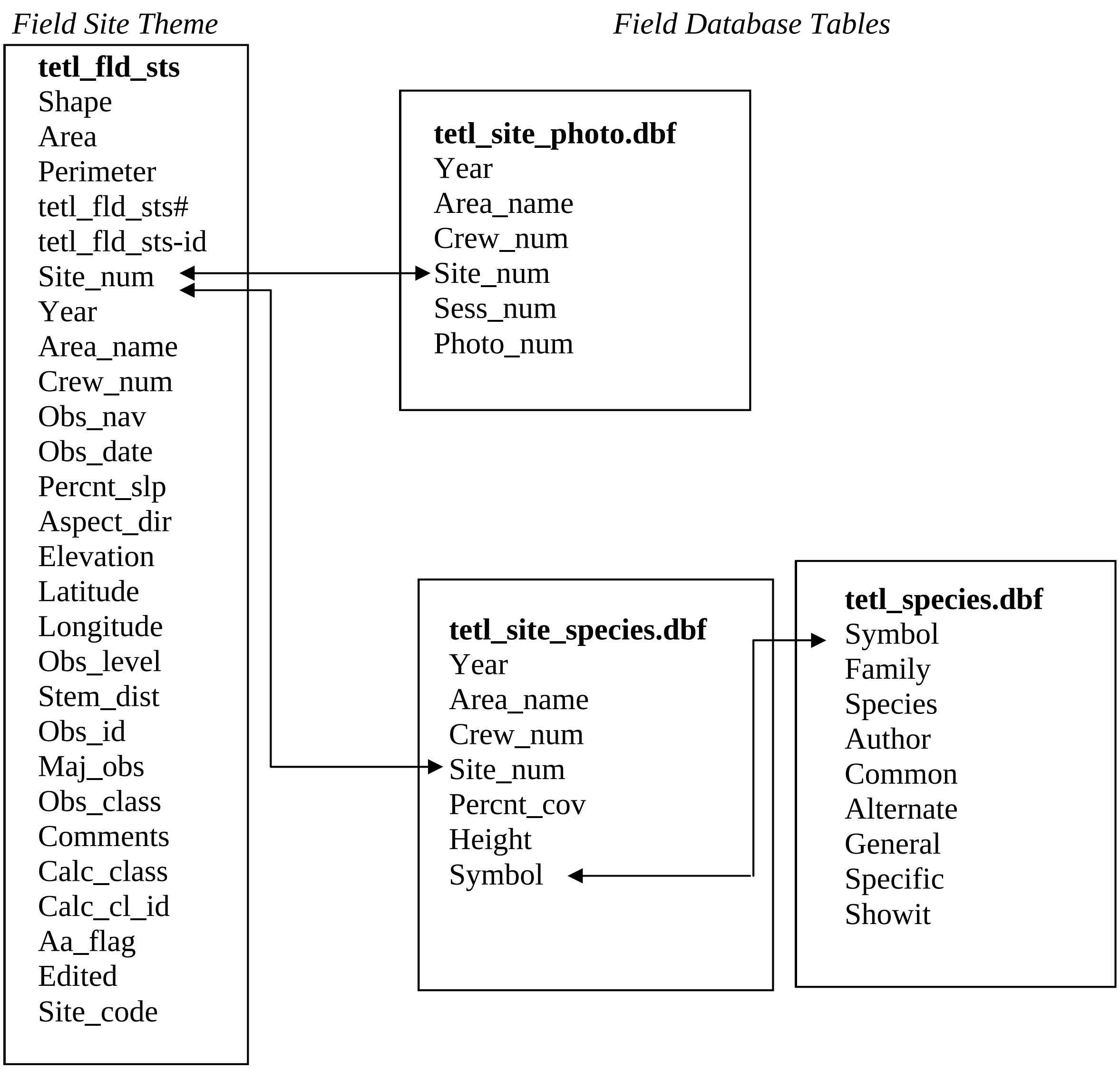
4. Determine if specific sites are to be compared. If only certain sites are to be examined, select yes. Next, select a field with which the DUFF field site theme will be queried. Finally, select a value to use as a limiter. This inquiry may run a long time due to large numbers of records being chosen.

Limitations of the DUFF Data and Photo Viewer Extension

1. If there is more than one view in the ArcView Project, the user will have to identify which view contains the field site theme.
2. The field site theme must be named with the same project name as the tables. (ie for Stony project: Stony_fld_sts, stony_species.dbf, stony_site_species.dbf, stony_site_photo.dbf.)
3. To sort the species box, the user needs to click on the column which they want sorted.
4. DUFF Photo tool looks specifically for .jpg files, not .jgw files.
5. If sites are currently selected when you use the Inquiry Button, no sites will be returned in response to your query regardless of the query. This is due to a bug in the program. To avoid this problem, deselect all sites before using the Inquiry Button. – added by Ducks Unlimited, Inc.

Appendix F. Structure of the DUFF Field Database

The field database is delivered as a field site polygon coverage and three related .dbf tables. The structure of the related tables is diagrammed below. These tables can be linked in MS Access or linked/joined in ArcView where they can also be related to the field site polygon coverage. A description of the fields in each table follows.



TETL_FLD_STS (polygon coverage) - ArcInfo coverage of the field sites.

Field	**Description**
AREA	ArcInfo internal field; area in coverage units
PERIMETER	ArcInfo internal field
COVERAGE	ArcInfo internal field
COVERAGE-ID	ArcInfo internal field
SITE_NUM	Field site number
YEAR	Year of field data collection
AREA_NAME	4 letter code for project area
CREW_NUM	ID number of crew that collected data
OBS_NAV	Navigator for field data collection
OBS_VEG	Vegetation caller for field data collection
OBS_REC	Recorder for field data collection
OBS_DATE	Date of field data collection
PERCNT_SLP	Percent slope of site
ASPECT_DIR	Aspect of site
LATITUDE	Latitude of site (only entered for non-preselected sites)
LONGITUDE	Longitude of site (only entered for non-preselected sites)
OBS_LEVEL	Observation level, where 1 = Observation made from within site, on the ground 2 = Observation made from above site (ie from helicopter) 3 = Observation made from a distance, outside of site 4 = Observation made from aerial photographs
STEM_DIST	Distance between tree stems (applies to Open or Woodland Needleleaf only)

OBS_ID	ID of observed class (ie classification assigned by vegetation caller)
MAJ_OBS	Level 1 class of classification hierarchy (ie forest, shrub, herbaceous, etc)
OBS_CLASS	Classification label assigned by vegetation caller
COMMENTS	Notes made by vegetation caller while observing the site
CALC_CLASS	Classification of site as calculated using the project decision tree
CALC_CL_ID	ID number of calculated class
AA_FLAG	Indicates if site was used as an accuracy assessment site or training data. 0 = site used for training 1 = site used for accuracy assessment
CODE	Code for the calculated class assigned to each site.
SITE_CODE	Site label created by combining the site number and a code for the calculated class.

TETL_SITE_PHOTO.dbf Dbase file containing site photo information

YEAR	Year of field data collection
AREA_NAME	4 letter code for project area
CREW_NUM	ID number of crew that collected data
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationship (ie each site may have multiple photos).
SESS_NUM	Session number for field data collection.
PHOTO_NUM	Photo number. Photos are numbered consecutively within each session.

TETL_SPECIES.dbf - The data in the following table are based on the PLANTS National Database developed by the National Resource Conservation Service. Edits have been made to some species codes to facilitate the use of the data with the DUFF data entry program. Also species have been added to the list (and a species code created) as necessary when compiling field data.

SYMBOL	Species code. Most of these are from the PLANTS National Database. When new species were added to the field database, a code was created to represent it.
FAMILY	Plant family.
SPECIES	Plant genus and species (or in some cases genus only)
AUTHOR	Author citation for species information.
COMMON	Common name.
ALTERNATE	Alternate name.
GENERAL	General plant type; used to pipe information correctly through the decision tree.
SPECIFIC	Specific plant type; used to pipe information correctly through the decision tree.
SHOWIT	Internal field used by the DUFF program.

TETL_SITE_SPECIES.dbf - Dbase table containing species composition information for each site. Each record describes an individual species observed at a site. Each site can have multiple records in this table depending on how many different species were observed within the site.

YEAR	Year of field data collection
AREA_NAME	4 letter code for project area
CREW_NUM	ID number of crew that collected data
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationship. Each site may have multiple species records in this table.
PERCNT_COV	Percent coverage of the species as observed at site by vegetation caller.
HEIGHT	Height of tree or shrub species at site as observed by vegetation caller.